Project Status Report

High End Computing Capability
Strategic Capabilities Assets Program

February 10, 2018

Dr. Rupak Biswas – Project Manager
NASA Ames Research Center, Moffett Field, CA
Rupak.Biswas@nasa.gov
(650) 604-4411

HECC Deploys Mitigations for Meltdown and Spectre Security Vulnerabilities

- HECC engineers deployed mitigations to address the Meltdown and Spectra security vulnerabilities on HECC systems quickly after the issue became known.
- The most vulnerable systems were patched first; these were primarily the front end systems, which had multiple users concurrently on the system. The compute nodes were updated in a rolling reboot fashion to minimize the impact on users. The system infrastructure resources will be updated during the next scheduled maintenance window.
- The HECC Application Performance and Productivity team ran benchmarks on the compute nodes to measure the impact of the security mitigations on codes. Performance was still within the expected range for each benchmark.
- The mitigations implemented are a partial fix for the security vulnerabilities. Additional mitigations will likely be needed, and are pending release from the hardware vendors.

Mission Impact: HECC specialists were able to quickly deploy mitigations to minimize the impact and risk to NASA resources and prevent security vulnerabilities.

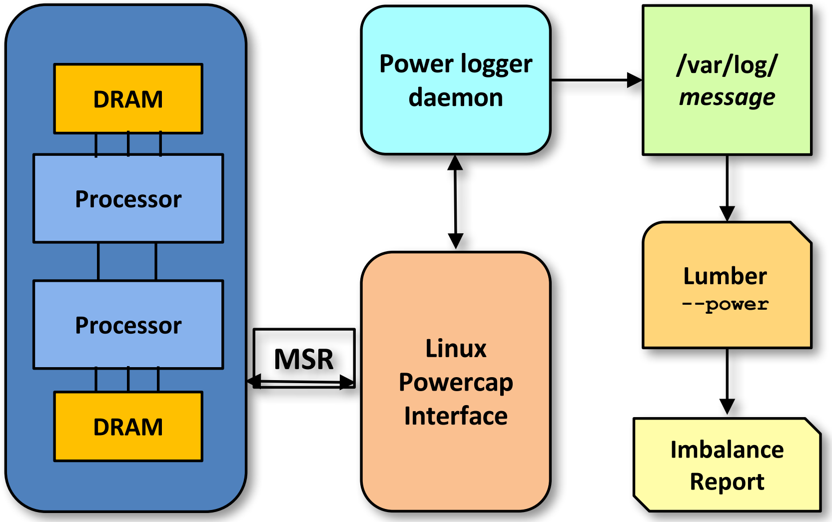
The analysis, testing, and deployment of the HECC security mitigations began within days of vendor releases of security vulnerability details.

POCs: Bob Ciotti, bob.ciotti@nasa.gov, (650) 604-4408, NASA Advanced Supercomputing (NAS) Division;
Davin Chan, davin.chan@nasa.gov, (650) 604-3613, NAS Division, CSRA LLC

APP Team Develops Process for Identifying Load Imbalance in PBS Jobs

- The HECC Application Performance and Productivity (APP) team recently developed a process for identifying PBS jobs exhibiting load imbalance, which may cause applications to run longer than necessary.
- The process is built on top of their framework that gathers energy usage data from running jobs and records it in system logs. The team uses the Lumber utility to scan those logs and to produce a report showing the energy consumption variation across a job's nodes and across the components within each node.
- Comparing the energy used by the two sockets in a node, the team is now able to identify jobs that have incorrectly bound execution threads to processor cores—leading to a performance issue that is easy to fix once it is identified.
- The APP team will produce the imbalance reports on a weekly basis and then help fix improper thread-binding issues. They will also use the report to identify other load balancing issues and work with users to address them.

Mission Impact: Identifying load imbalance in the HECC job workload enables optimal use of system resources, effectively increasing the amount of science and engineering return.



The framework for monitoring the energy usage of PBS jobs uses a logging daemon that gets information from the nodes via the Linux Powercap interface. The daemon writes the information to system logs, which are then read by the Lumber utility to produce a report showing jobs with load imbalance.

POCs: Robert Hood, robert.hood@nasa.gov, (650) 604-0740, NASA Advanced Supercomputing (NAS) Division, CSRA LLC; David Barker, david.p.barker@nasa.gov, (650) 604-4292, NAS Division, Supersmith

New SBU Rates Established for HECC Resource Usage

- The HECC Application Performance and Productivity (APP) team finished an update of the six benchmark applications used to establish the Standard Billing Unit (SBU) on HECC resources, and calculated new SBU rates (SBU2 rates).
- The last update, based on Intel Westmere processors, occurred in 2011. Updating the suite makes it more representative of current production workloads and state-of-the-art hardware.
- A few highlights:
  - The HECC SBU suite consists of applications from space sciences (Enzo), computational fluid dynamics (FUN3D, OVERFLOW, USM3D), and climate/weather modeling (GEOS-5, nuWRF).
  - The timings used in the calculation were obtained for the main iteration phase of most applications, so that the results are more reflective of long-running jobs.
  - The final rates were calculated from benchmark timings obtained on SUSE Linux Enterprise Server 12.
- The APP team calculated a factor of 0.2539 to map from old SBUs to new SBUs. This conversion factor keeps the total high-end computing production capacity constant across the change in rates.

Mission Impact: By establishing charging rates that reflect the power of resources to compute the NASA workload, HECC ensures that user demand across the various resource types will be balanced.

SBU Version 2	NAS Westmere	NAS Sandy Bridge	NAS Ivy Bridge	NAS Haswell	NAS Broadwell	NAS Skylake
FUN3D	0.28	0.42	0.65	0.70	1.00	1.60
GEOS-5	0.29	0.46	0.64	0.79	1.00	1.51
OVERFLOW	0.27	0.52	0.71	0.86	1.00	1.64
USM3D	0.27	0.48	0.68	0.87	1.00	1.54
nuWRF	0.32	0.48	0.66	0.82	1.00	1.61
SBU2 Rate	**0.29**	**0.47**	**0.66**	**0.80**	**1.00**	**1.58**
SBU1 Rate	**1.00**	**1.82**	**2.52**	**3.34**	**4.04**	**6.36**
Relative increase vs. SBU1	**1.16**	**1.03**	**1.05**	**0.96**	**1.00**	**1.00**

HECC's Application Performance and Productivity team performed a calculation of SBU2 rates for different node types of the current HECC resources, using six SBU benchmarks. The new rates show a relative increase in the rate for Westmere processors and a nominal change for the other processor types, as compared to SBU1 rates.

POCs: Henry Jin, haoqiang.jin@nasa.gov, (650) 604-0165, NASA Advanced Supercomputing (NAS) Division;
Robert Hood, robert.hood@nasa.gov, (650) 604-0740, NAS Division, CSRA LLC

Engineering Servers and Services Team Upgrades to Jamf Pro 10 for Macs

- Jamf Pro is the primary tool used by the Engineering Servers and Services (ESS) team to maintain patch compliance on NAS facility workstations.
- Key improvements in version 10 include:
  - A new interface that provides administrators greater flexibility in navigation and reporting.
  - Improved patch management that automatically tracks well-known software titles and notifies the administration team of new versions.
  - A fully customizable Self Service app that provides end users with a positive native Mac experience. Dynamic buttons inform the user of policy progress, and a history tab reveals previously downloaded patches.
  - Support for macOS High Sierra.
- The ESS team is now working on all the policies, configuration profiles, and images necessary to upgrade local workstations to macOS 10.13 High Sierra.

Mission Impact: Jamf Pro 10 improves patch compliance, and is instrumental in the development of macOS High Sierra for NAS facility workstations.

Jamf Pro 10, formerly Casper Suite, includes a major interface overhaul, including a newly designed Self Service application.

POC: Ted Bohrer, theodore.w.bohrer@nasa.gov, (650) 604-4335, NASA Supercomputing Division, ADNET Systems

Red Hat Enterprise Linux Release 7 Upgrade of Linux Workstations Completed

- HECC's Engineering Servers and Services (ESS) team completed the upgrade of over 100 workstations to Red Hat Enterprise Linux Release 7.
- Enhancements in the upgrade include:
  - Conversion of desktop environment to Gnome 3 or KDE.
  - Upgrade to CFEngine Version 3, providing full configuration control for Red Hat 7 modules.
  - Change to using XFS, which allows up to 500-TB file systems on each workstation.
  - Conversion to FirewallD xml scripts, which are more flexible and powerful than the systems iptables used in Red Hat 6.
  - Use of systemd, which allows applications and services to start at boot time.
  - Addition of structured logging, which makes the log analysis tools more powerful.
  - Implementation of NASA's Center for Internet Security (CIS) Benchmark for Red Hat 7.
- The ESS team continues with the upgrade of HECC infrastructure servers to Red Hat Enterprise Linux 7.

Mission Impact: The Red Hat Enterprise Linux Release 7 upgrade provides HECC staff with the most current features available in Release 7, as well as access to the latest software applications.

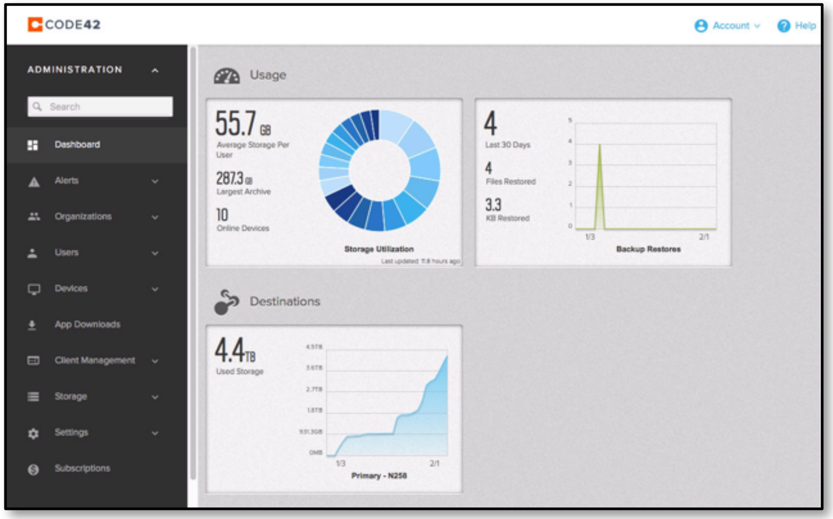
Red Hat Enterprise Linux Release 7 is the latest Red Hat version for enterprise environments.

POC: Chris Shaw, robert.c.shaw@nasa.gov, (650) 604-4354, NASA Advanced Supercomputing Division, CSRA LLC

ESS Team Begins Migration to Code42 CrashPlan for Improved Mac Backups

- The Engineering Servers and Services (ESS) team completed development of Code42 CrashPlan as the backup solution for HECC staff Macs, replacing ASG Time Navigator.
- Key benefits of CrashPlan include:
  - Web-based administration.
  - Capability to independently write to multiple backup locations.
  - Association of a backup to a user rather than a system.
  - Reduced amount of daily maintenance.
- The first of several new backup servers is now online and in production.
- The transition to CrashPlan is a mostly automated background process that is nearly seamless to the users.
  - Administrators only need to interact with the system for a few minutes to kick-start the process, and the rest happens in the background.
  - During the transition, all previous backups are retained on Time Navigator until the data retention period expires (90 days from migration).
- The ESS team is in the process of migrating all systems from Time Navigator to CrashPlan. They are also integrating CrashPlan with the annual OS upgrade process to expedite the process.

Mission Impact: CrashPlan provides HECC staff with a more stable Mac backup solution for their systems, requiring less administrative support to ensure stable backups, and reduce annual upgrade time.



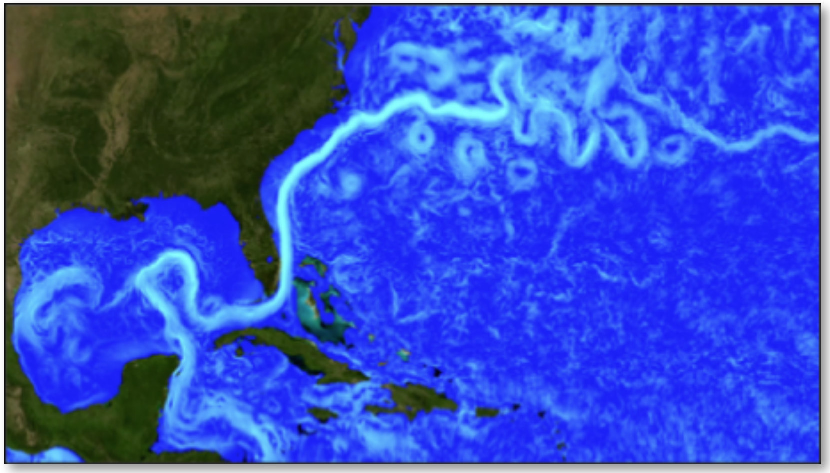
Screenshot of the backup status overview, as seen from the Code42 CrashPlan administration console.

POC: Ted Bohrer, theodore.w.bohrer@nasa.gov, (650) 604-4335, NASA Supercomputing Division, ADNET Systems

Exploring Ocean Currents Through Petascale Simulations and Visualization

- Researchers from the Estimating the Circulation and Climate of the Ocean (ECCO) project are using a HECC-developed visualization tool to analyze a high-resolution global ocean simulation, which ran Pleiades and produced 5 petabytes of data.
- With the visualization displayed across the 128-screen HECC hyperwall, the interactive tool enables scientists to dive deeply through ocean layers to see details that were missed in previous analyses of their simulation. Findings include:
  - Artifacts of the model's surface forcing due to the interpolation of atmospheric fields.
  - Small salty lenses of fluid rotating at depth after ice cracking events.
  - Seasonal changes of relative vorticity and vertical velocity.
- Results help the researchers better understand the ocean's interactions with sea ice, ice sheets, and the atmosphere, enabling them to learn more about ocean ecology and its role in the carbon cycle.
- The simulation is also being used to help NASA design satellite missions, retrieval algorithms, and calibration/verification experiments.

Mission Impact: Enabled by HECC resources, this work will help design NASA missions such as the Surface Water and Ocean Topography, and will aid researchers in understanding and potentially predicting the impact of global ocean circulation on climate.



Detail of surface ocean current speed in the Gulf of Mexico and surrounding regions from a global 1-kilometer ECCO simulation. This video shows the tremendous complexity and variability of the ocean, including surface signatures of geostrophic eddies, submesoscale eddies, and internal tides. *Christopher Henze, NASA/Ames*

POCs: Christopher Hill, cnh@mit.edu, (617) 253-6430, Massachusetts Institute of Technology;
Dimitris Menemenlis, menemenlis@jpl.nasa.gov, (818) 354-1656, NASA Jet Propulsion Laboratory

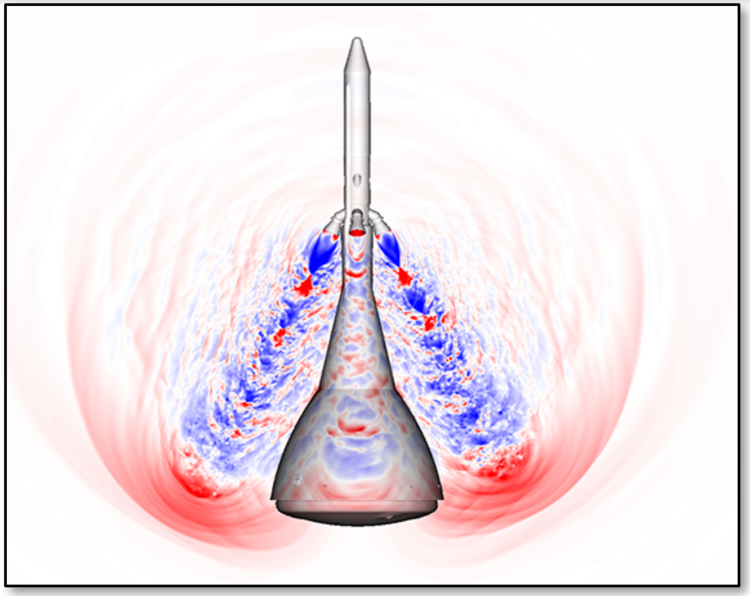
HECC provided supercomputing resources and services in support of this work.

Predicting Vibrations on the Launch Abort Vehicle to Keep Astronauts Safe

- Research scientists at NASA Ames produced 350-million degrees of freedom simulations of the QM-1 abort motor ground test and three launch abort scenarios to investigate transient and vibrational loads on the Launch Abort Vehicle (LAV).
- Simulations of the QM-1 launch abort motor test (6/17) were performed in advance to ensure the test would proceed safely and to minimize data collection risks.
- Using NASA's Launch, Ascent and Vehicle Aerodynamics (LAVA) CFD code, the turbulence-resolving simulations increased the confidence in LAVA's ability to accurately simulate the complex physics at play during launch abort scenarios.
  - The predicted maximum transient load from the LAVA simulations for the QM-1 test closely match the experimentally measured peak.
  - Vibrational loads coming from acoustic waves are also well captured, leading to agreement within 2% of measured vibrations.
  - Simulations ran until 0.3 seconds after ignition of the launch abort motors, allowing the characterization of vibrations ranging from 10 Hz to 3,500 Hz over most of the vehicle.
- The scientists continue to simulate more launch abort scenarios at varying angles of attack to help reduce uncertainty in the expected loads for the LAV.

HECC provided supercomputing resources and services in support of this work.

Mission Impact: The QM-1 and three LAV abort simulations, run on Pleiades, help researchers understand how the vibration levels change when taking into account the surface of the crew vehicle, and directly influence the requirements for the final LAV design.



Snapshot from a simulations of pad abort at about 0.051 seconds after ignition of the launch abort motors. *Francois Cadieux, Michael Barad, NASA/Ames*

POCs: Francois Cadieux, francois.cadieux@nasa.gov, (650) 6032; Cetin Kiris, cetin.c.kris@nasa.gov, (650) 604-4485, NASA Advanced Supercomputing Division

HECC Facility Hosts Several Visitors and Tours in January 2018

- HECC hosted 8 tour groups in January; guests learned about the agency-wide missions being supported by HECC assets, and some groups also viewed the D-Wave 2X quantum computer system. Visitors this month included:
  - Lt. Col. Tim Stevens and Lt. Col. Nathan Diller, United States Air Force, Joint Staff Innovation Group for the Vice Chairman of the Joint Chiefs of Staff.
  - His Excellency Casper Klynge, The Danish Ambassador for Technology, Kingdom of Denmark, and his group from their local Palo Alto office.
  - The New Blue of Yale University women's a cappella group, hosted by the Ames Women's Women's Influence Network.
  - A small group from the NASA Shared Services Center P-Card transition team, Stennis Space Center, who held a Town Hall meeting at Ames, toured the center as guests.
  - A large group from the John F. Kennedy School of Government at Harvard University visited Ames to learn about innovation, science, and technology in the agency.

NAS Division Chief Piyush Mehrotra presented an overview of the facility's high-end computing capabilities and scientific research to a large group from the John F. Kennedy School of Government at Harvard University.

POC: Gina Morello, gina.f.morello@nasa.gov, (650) 604-4462, NASA Advanced Supercomputing Division

Papers

- **AIAA SciTech Forum**, Kissimee, Florida, January 8-12, 2018.
  - "**Nonlinear Evolution and Breakdown of Azimuthally Compact Crossflow Vortex Pattern over a Yawed Cone**," M. Choudhari, F. Li, P. Paredes. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1823
  - "**Sub-grid Scale Modeling of Turbulent Spray Flame using Regularized Deconvolution Method**," Q. Wang, M. Ihme, X. Zhao. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-2082
  - "**Tetrahedral-Mesh Simulations of Shock-Turbulence Interaction**," B. Venkatachari, C.-L. Chang. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1529
  - "**Nosetip Bluntness Effects on Transition at Hypersonic Speeds: Experimental and Numerical Analysis Under NATO STO AVT-240**," P. Paredes, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-0057
  - "**Mixing in High Pressure Flows: The Influence of the Number of Species**," L. Sciacovelli, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1189
  - "**Reynolds-Stress Budgets in an Impinging Shock Wave/Boundary-layer Interaction**," M. Vyas, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1299
  - "**The Thermodynamic Regime During Mixing Under High-Pressure Conditions**," G. Castiglioni, J. Bellan. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1188
  - "**Grid Convergence for Three Dimensional Benchmark Turbulent Flows**," B. Diskin, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1102
  - "**Computational Investigation of the Flow Distortions in a Mach 6 Converging-Diverging Facility Nozzle**," R. Shenoy, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1142

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- **AIAA SciTech Forum** (cont).
  - "**Computational Investigation of the Flow Distortions in a Mach 6 Converging-Diverging Facility Nozzle**," R. Shenoy, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1142
  - "**Aeromechanics Analysis of a Distortion-Tolerant Fan with Boundary Layer Ingestion**," M. Bakhle, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-1891
  - "**Characterization of Freestream Disturbances in Conventional Hypersonic Wind Tunnels**," L. Duan, M. Choudhari, A. Chou, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-0347
  - "**An Aeroelastic Coupling Framework for Time-Accurate Analysis and Optimization**," K. Jacobson, J. Kiviaho, et al. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-0100
  - "**A Comparison of Uncertainty Quantification Methods on Benchmark Problems for Space Deployable Structures**," L. Peterson, M. Mobrem. *
    https://arc.aiaa.org/doi/abs/10.2514/6.2018-0452
- "**A Self-Consistent Model of the Solar Tachocline**," T. Wood, N. Brummell, arXiv:1801.02565 [astro-ph.SR], January 8, 2018. *
  https://arxiv.org/abs/1801.02565
- "**Estimating Regional-Scale Methane Flux and Budgets using CARVE Aircraft Measurements over Alaska**," S. Hartery, et al., Atmospheric Chemistry and Physics, vol. 18, January 8, 2018. *
  https://www.atmos-chem-phys.net/18/185/2018/

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- “**Atmospheric Escape from the TRAPPIST-1 Planets and Implications for Habitability**,” C. Dong, M. Jin, et al., PNAS (National Academy of Sciences), vol. 115, January 9, 2018. *
  http://www.pnas.org/content/115/2/260
- “**Numerical Simulations of Multiphase Winds and Fountains from Star-Forming Galactic Disks: I. Solar Neighborhood TIGRESS Model**,” C.-G. Kim, E. Ostriker, arXiv:1801.03952 [astro-ph.GA], January 11, 2018. *
  https://arxiv.org/abs/1801.03952
- ”**The Propitious Role of Solar Energetic Particles in the Origin of Life**,” M. Lingam, C. Dong, et al., The Astrophysical Journal, vol. 853, no. 1, January 17, 2018. *
  http://iopscience.iop.org/article/10.3847/1538-4357/aa9fef/meta
- “**Sun-to-Earth MHD Simulation of the 14 July 2000 ‘Bastille Day’ Eruption**,” T. Török, et al., arXiv:1801.05903 [astro-ph.SR], January 18, 2018. *
  https://arxiv.org/abs/1801.05903
- “**No Assembly Required: Mergers are Most Irrelevant for Growth of Low-Mass Dwarf Galaxies**,” A. Fitts, et al., arXiv:1801.06187 [astro-ph.GA], January 18, 2018. *
  https://arxiv.org/abs/1801.06187
- “**Cirum-Antarctic Shoreward Heat Transport Derived from an Eddy- and Tide-Resolving Simulation**,” A. Stewart, A. Klocker, D. Menemenlis, Geophysical Research Letters, January 19, 2018. *
  http://onlinelibrary.wiley.com/doi/10.1002/2017GL075677/full

** HECC provided supercomputing resources and services in support of this work*

Presentations

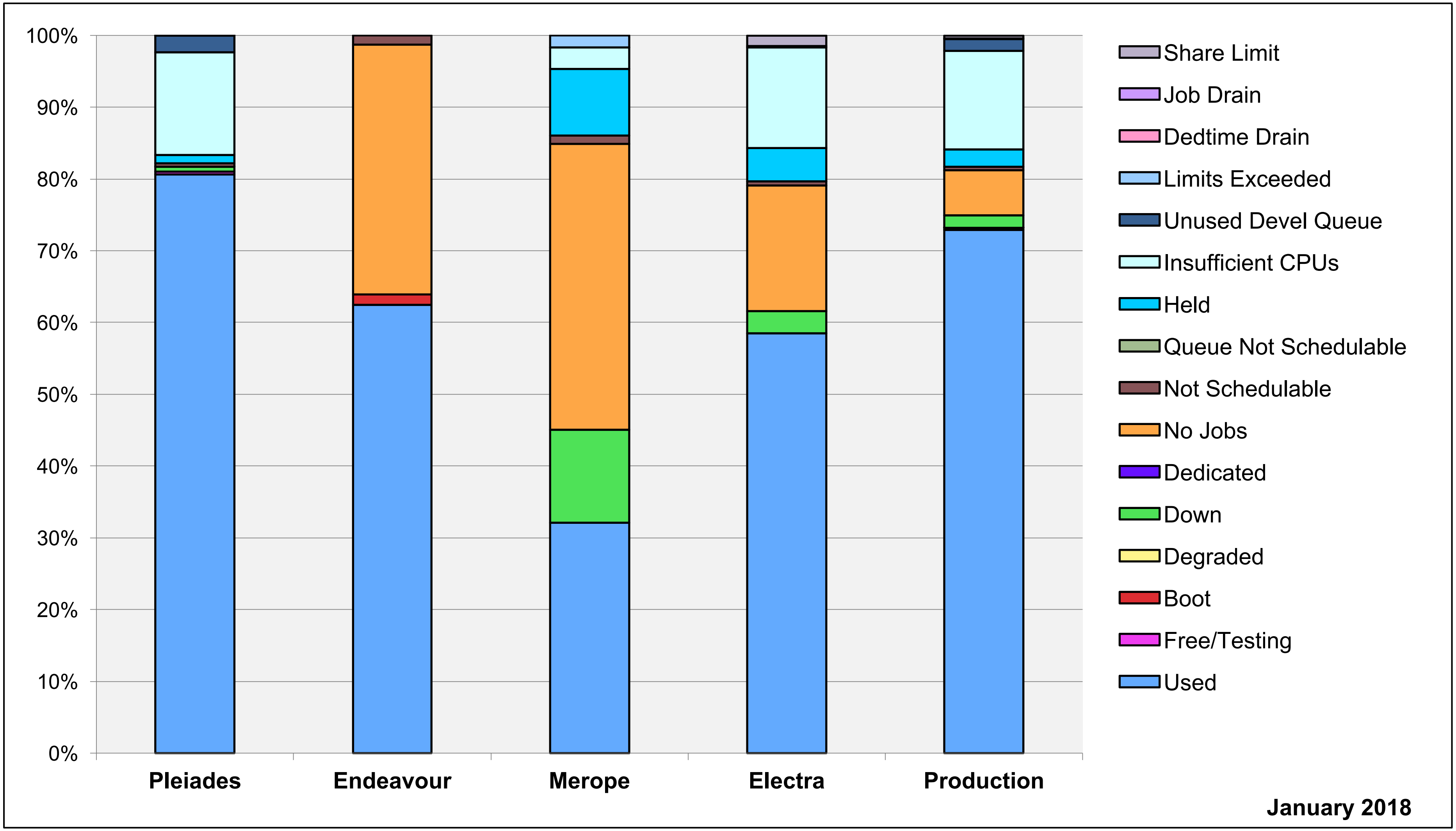
- **AIAA SciTech Forum**, Kissimee, Florida, January 8-12, 2018.
  - “**Contributions to HiLiftPW-3 Using Structured, Overset Grid Methods**,” J. Goder, T. Pulliam, J. Jensen. *https://arc.aiaa.org/doi/abs/10.2514/6.2018-1039**
  - “**High-Fidelity Computational Aerodynamics of Multi-Rotor Unmanned Aerial Vehicles**,” P. Ventura Diaz, S. Yoon.* *https://arc.aiaa.org/doi/abs/10.2514/6.2018-1266*
  - “**Formulation and Implementation of Inflow/Outflow Boundary Conditions to Simulate Propulsive Effects**,” D. Rodriguez, M. Aftosmis, M. Nemec.* *https://arc.aiaa.org/doi/abs/10.2514/6.2018-0334*
  - “**3rd High-Lift Workshop Summary Paper – OpenFOAM STAR-CCM+ & LAVA Simulations on Unstructured Grids**,” N. Ashton, M. Denison, M. Zastawny. * *https://arc.aiaa.org/doi/abs/10.2514/6.2018-1253*
  - “**LAVA Simulations for the 3rd AIAA CFD High Lift Prediction Workshop using Body Fitted Grids**,” J. Jensen, G.-D. Stich, J. Housman, M. Denison, C. Kiris.* *https://arc.aiaa.org/doi/abs/10.2514/6.2018-2056*
  - “**Computational Investigation of Nominally-Orthogonal Pneumatic Active Flow Control for High-Lift Systems**,” S. Hosseini, C. Van Dam, S. Pandya.* *https://arc.aiaa.org/doi/abs/10.2514/6.2018-0559*
- **American Helicopter Society Meeting**, San Francisco, California, January 16-19, 2018.
  - “**High-Fidelity Computational Aerodynamics of the Elytron 4S UAV**,” P. Ventura Diaz, S. Yoon.
  - “**A Conservative, Scalable, Space-Time Blade Element Rotor Model for Multi-Rotor Vehicles**,” J. Chiew, M. Aftosmis.*
- “**Probabilistic Assessment of Asteroid & Entry Properties Producing Tunguska-Like Airbursts**,” L. Wheeler, D. Mathias, Tunguska Workshop, NASA Ames, January 16, 2018.*

** HECC provided supercomputing resources and services in support of this work*

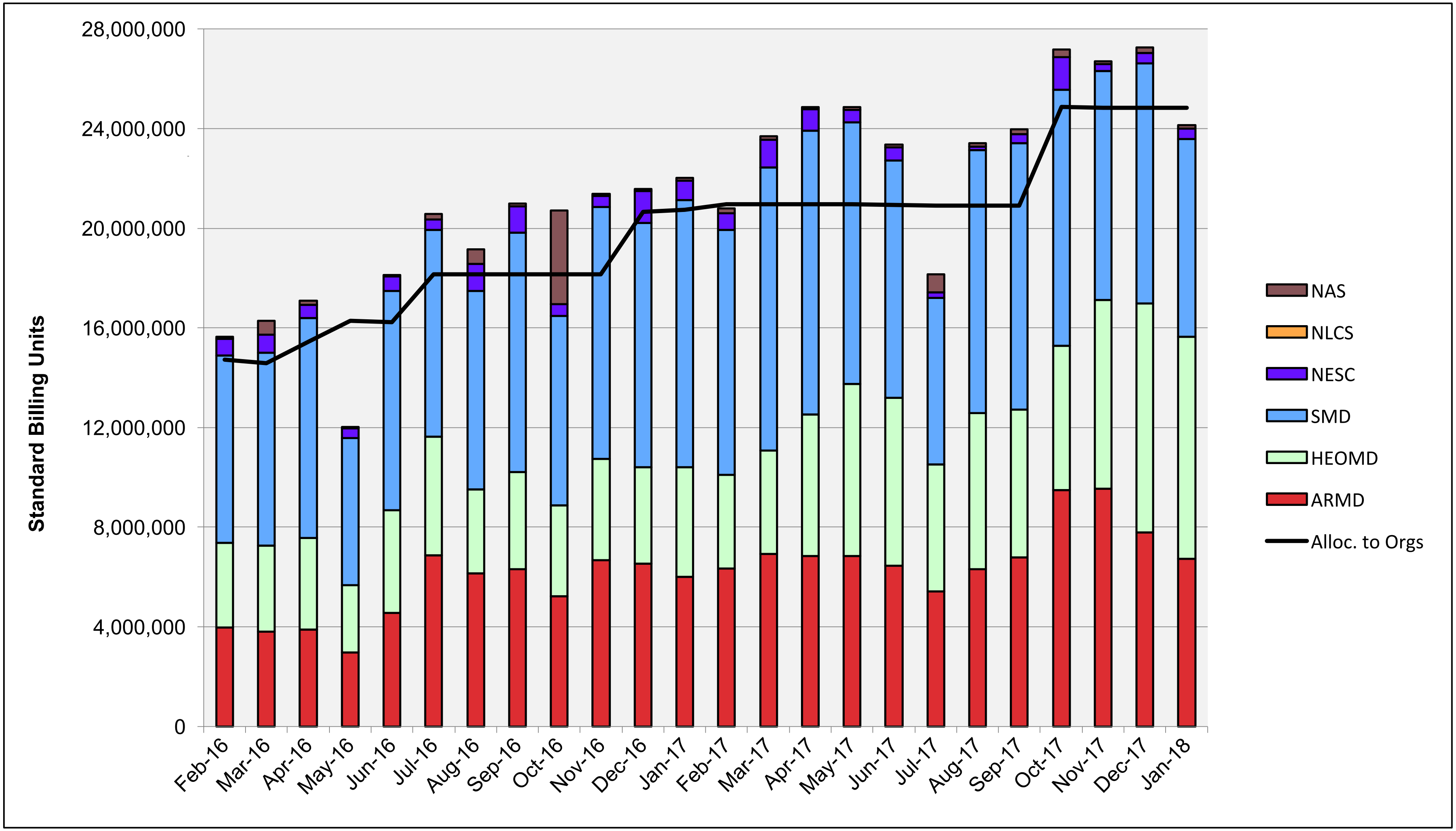
News and Events

- **Galactic Center: Scientists Take Viewers to the Center of the Milky Way**, *Chandra X-ray Center (operated for NASA by the Smithsonian Center for Astrophysics)*, January 10, 2018—Scientists in the University of Delaware's Department of Physics & Astronomy created an immersive 360-degree visualization of the center of the Milky Way galaxy using data from NASA's Chandra X-ray Observatory. Hydrodynamic simulations and visualization computations were run on the Pleiades supercomputer.
  http://chandra.harvard.edu/photo/2018/gcenter360/
- **A Hybrid Quadcopter for Longer Flights, Quieter Skies**, *NAS video feature*, January 10, 2018—High-fidelity simulations run on the Pleiades supercomputer are helping aeronautics engineers discover ways to make multi-rotor drones fly longer and quieter.
  https://www.nas.nasa.gov/publications/articles/feature_hybrid_UAVs_VenturaDiaz.html
- **NASA Brought Mars to Earth at This Year's CES**, *Adweek*, January 19, 2018—To support the agency's presence at the Consumer Electronics Show (CES) in Las Vegas, NAS staff provided a new drone video produced by HECC visualization experts, and several posters featuring science and technology results enabled by Pleiades. NASA Ames Public Affairs Officer Kimberly Minafra is featured with one of the drone models in the booth.
  http://www.adweek.com/digital/nasa-brought-mars-to-earth-at-this-years-ces/
- **Spinoff 2018 Highlights Space Technology Improving Life on Earth**, *NASA HQ press release*, January 24, 2018—The 2018 edition of NASA's annual Spinoff publication, features 49 technologies the agency helped create that are used in almost every facet of modern life. Among them: the Pegasus 5 software developed by NAS Division aerospace engineer Stuart Rogers. Pegasus 5, which reduces both cost and time required to design, test, and build new aircraft and spacecraft.
  https://www.nasa.gov/press-release/spinoff-2018-highlights-space-technology-improving-life-on-earth
  https://spinoff.nasa.gov/Spinoff2018/t_2.html

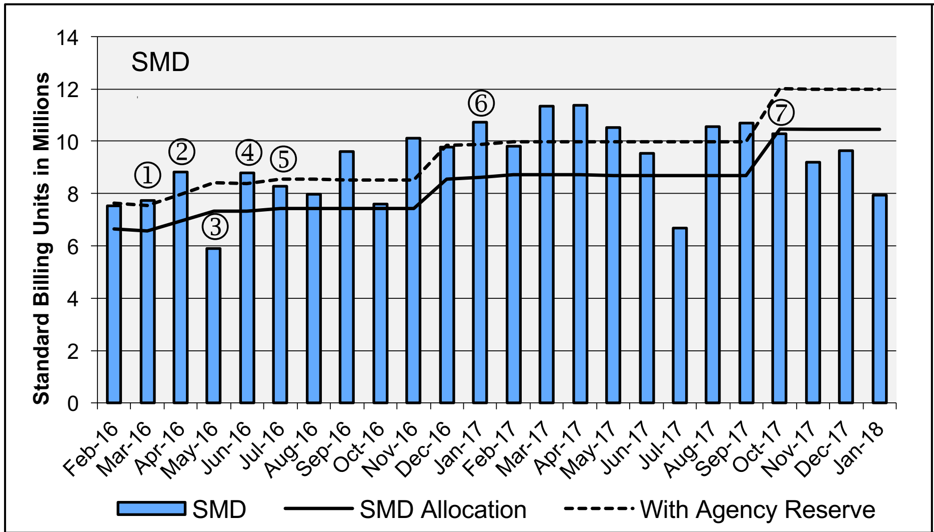
HECC Utilization

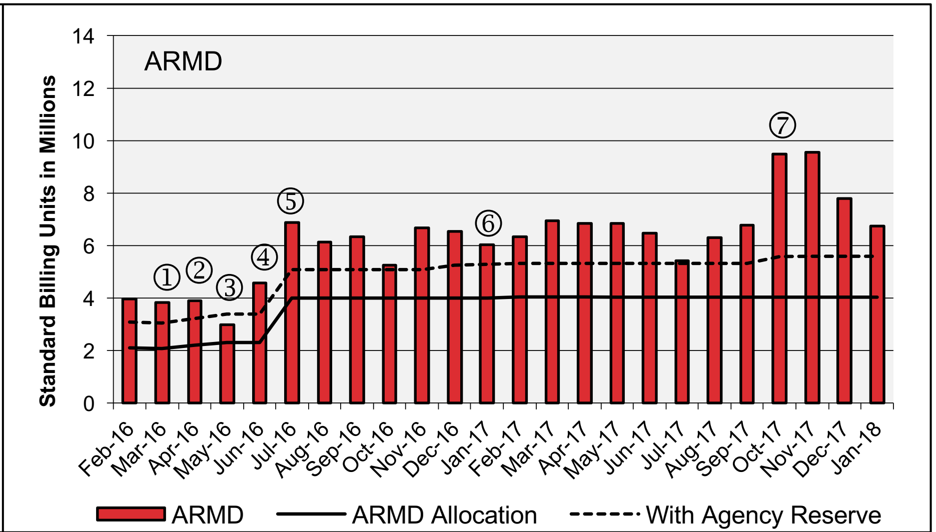


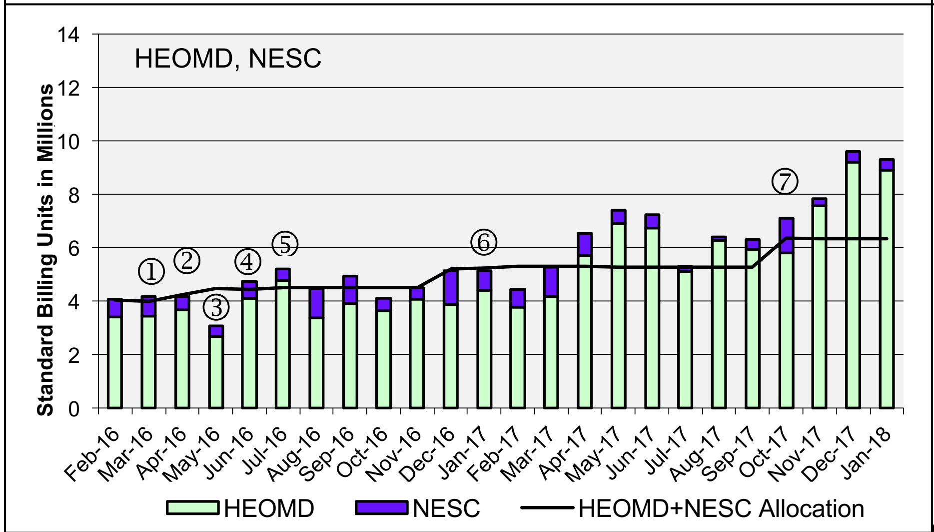
HECC Utilization Normalized to 30-Day Month



HECC Utilization Normalized to 30-Day Month

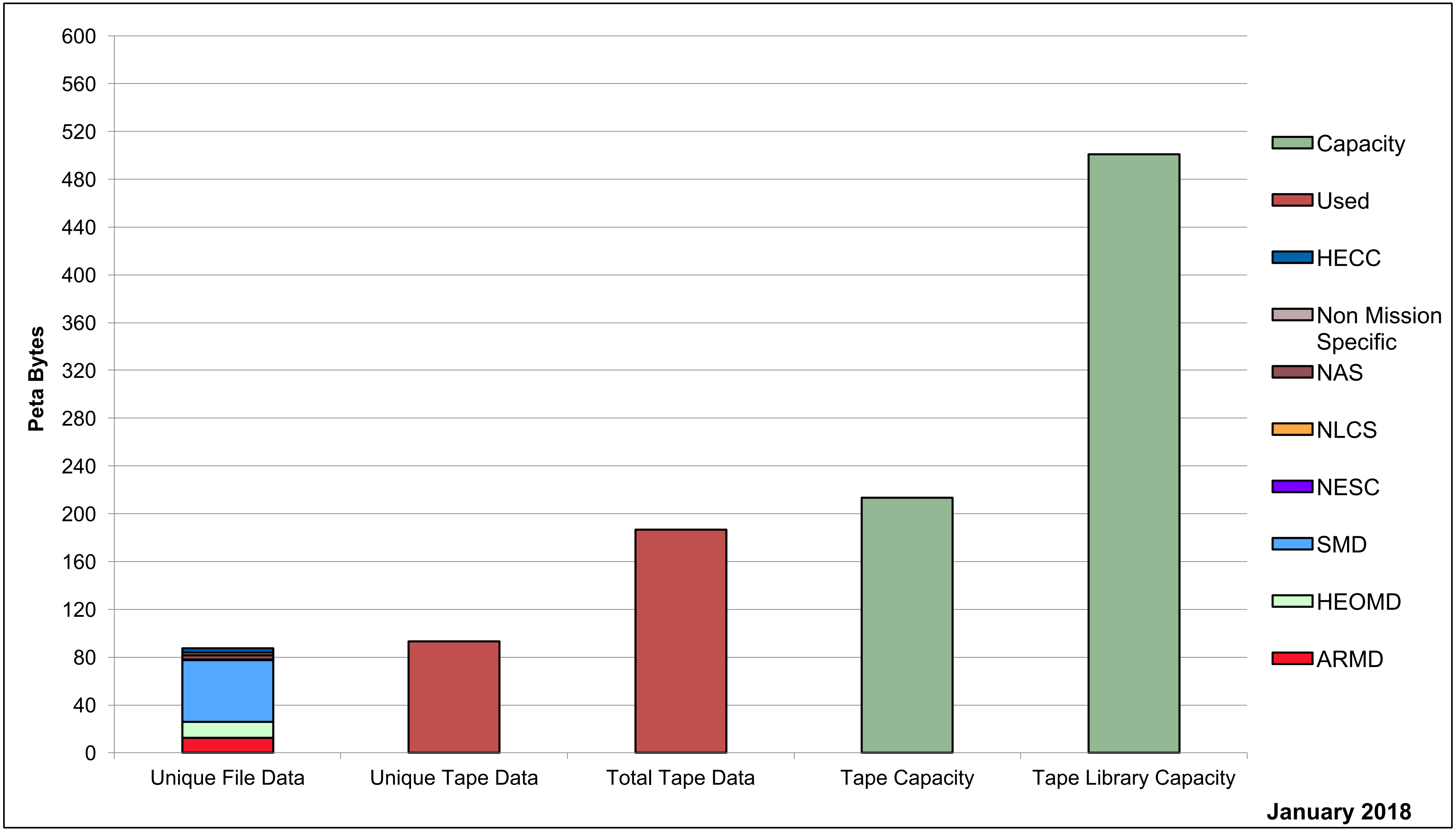




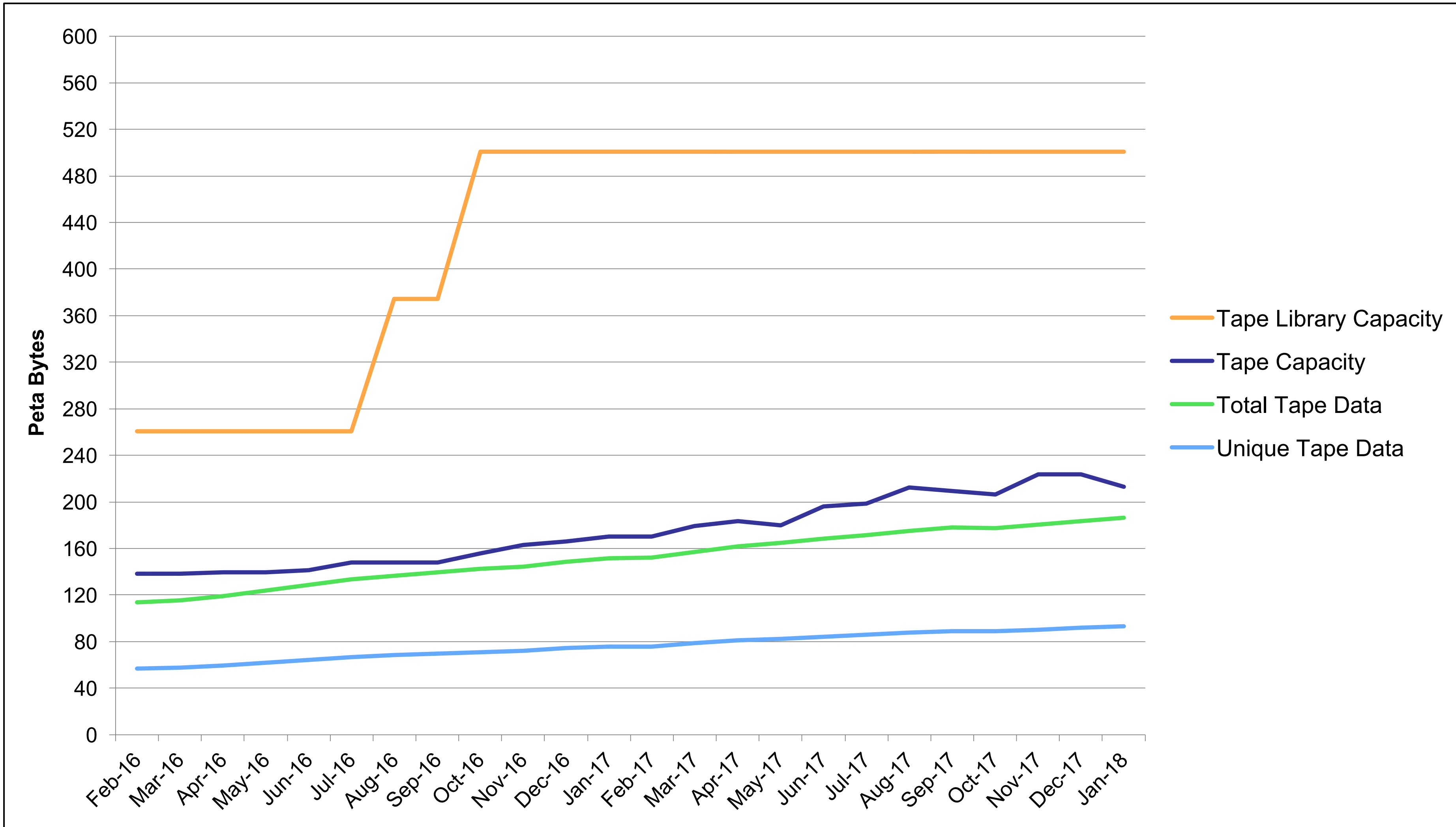


① 16 Westmere racks retired from Pleiades
② 10 Broadwell racks added to Pleiades
③ 4 Broadwell racks added to Pleiades
④ 14 (All) Westmere racks retired from Pleiades
⑤ 14 Broadwell Racks added to Pleiades
⑥ 16 Electra Broadwell Racks in Production, 20 Westmere 1/2 racks added to Merope
⑦ 4 Skylake E Cells (16 D rack equivalents) added to Electra

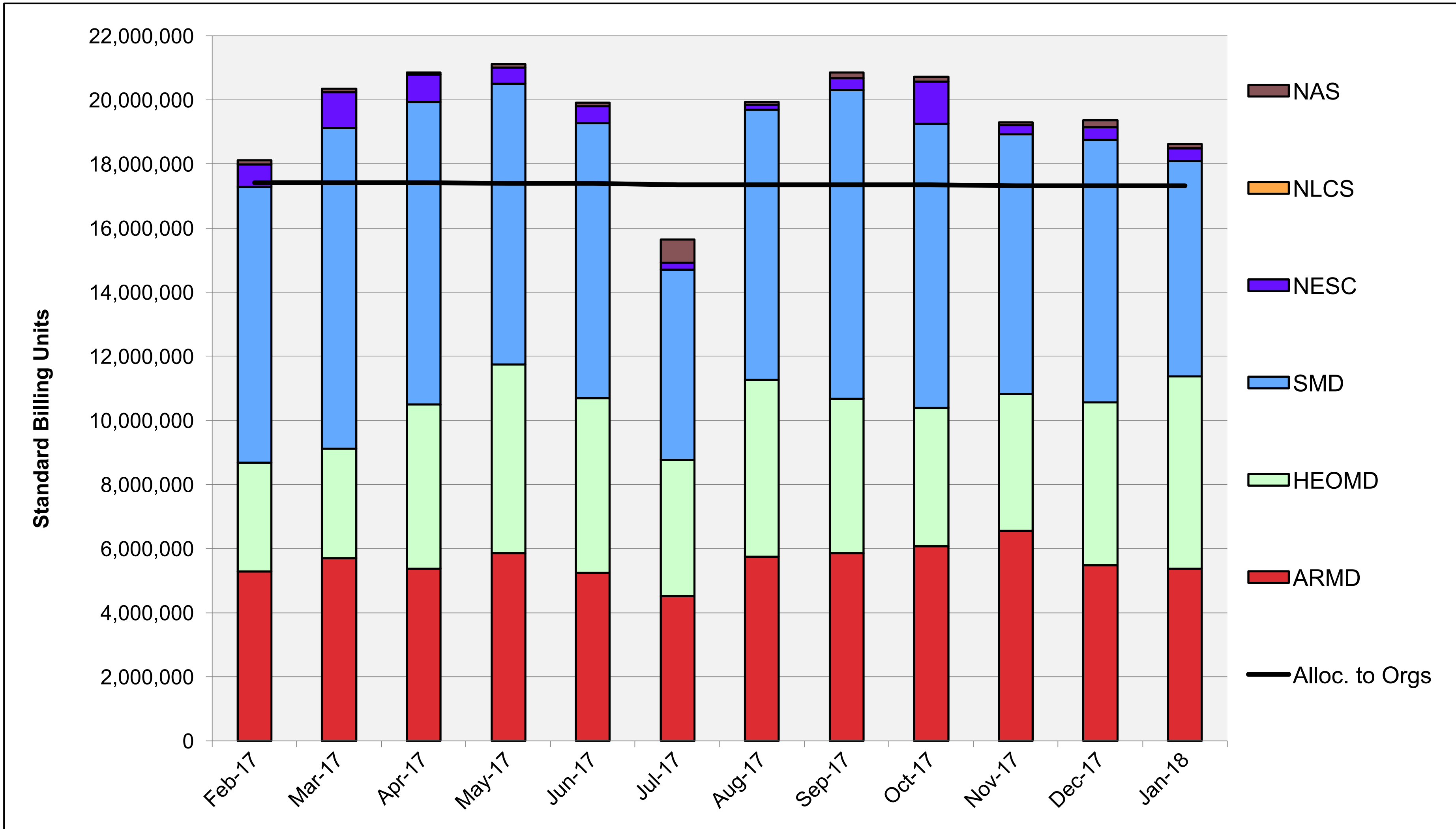
Tape Archive Status



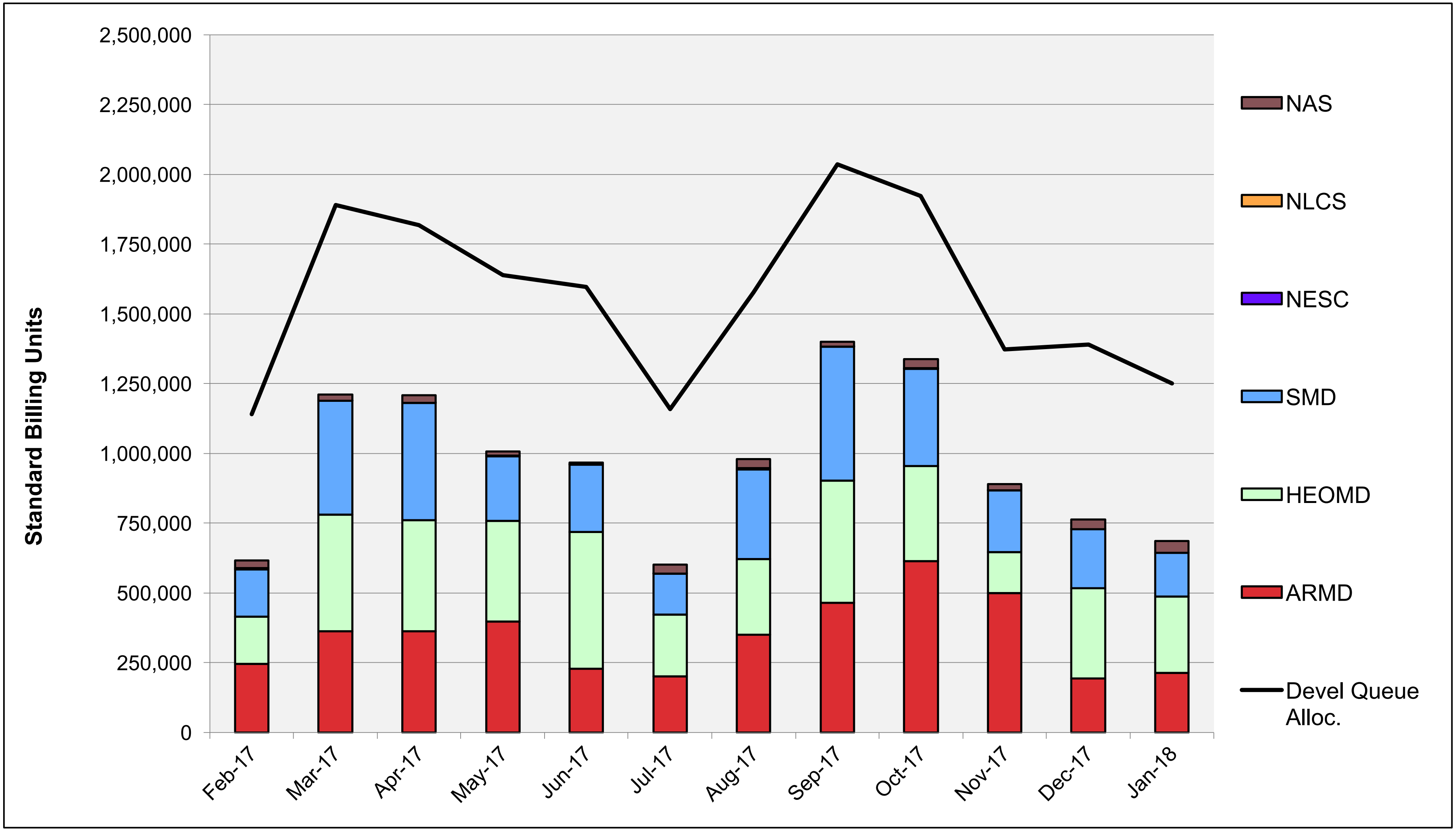
Tape Archive Status



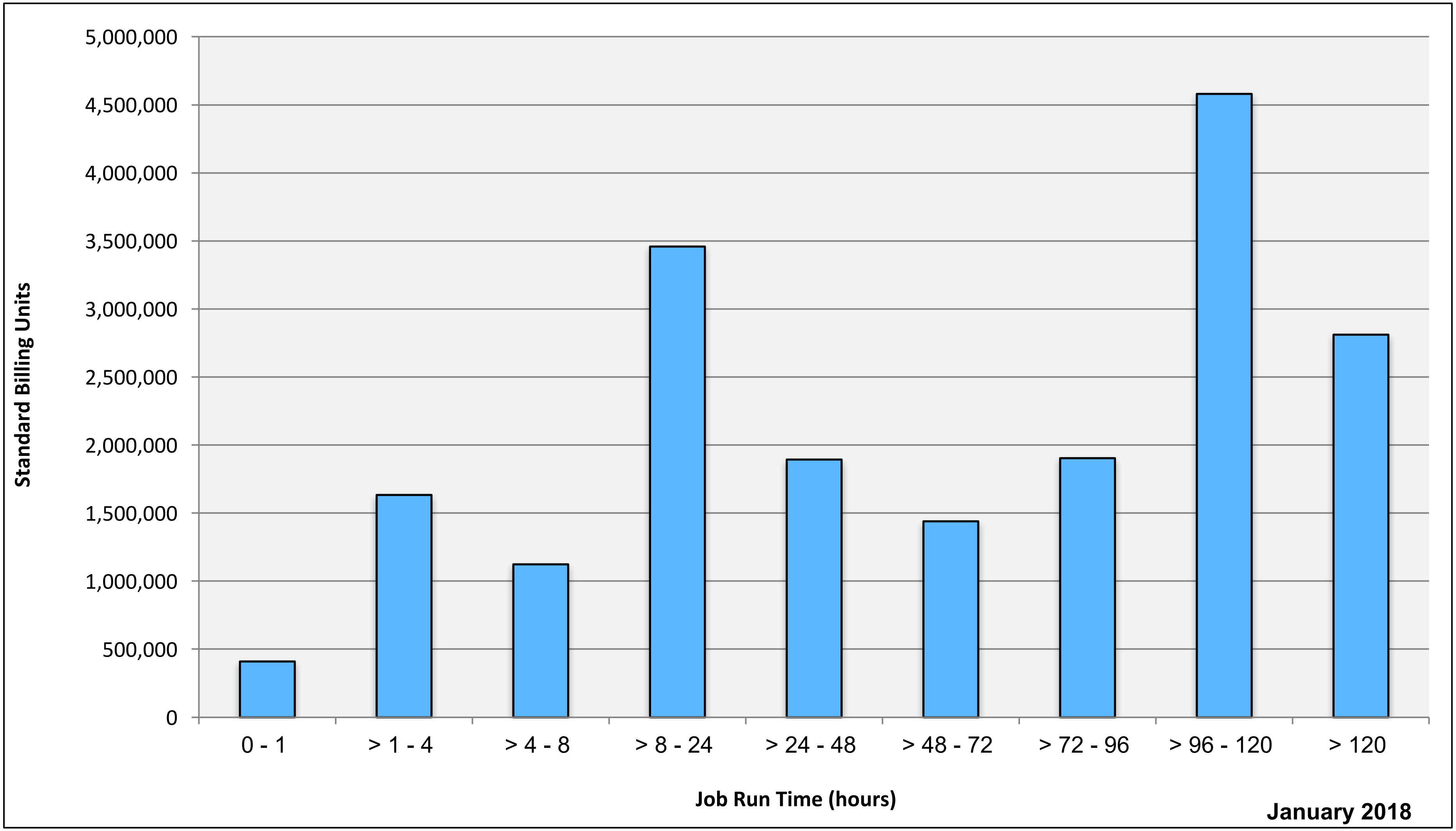
Pleiades:
SBUs Reported, Normalized to 30-Day Month



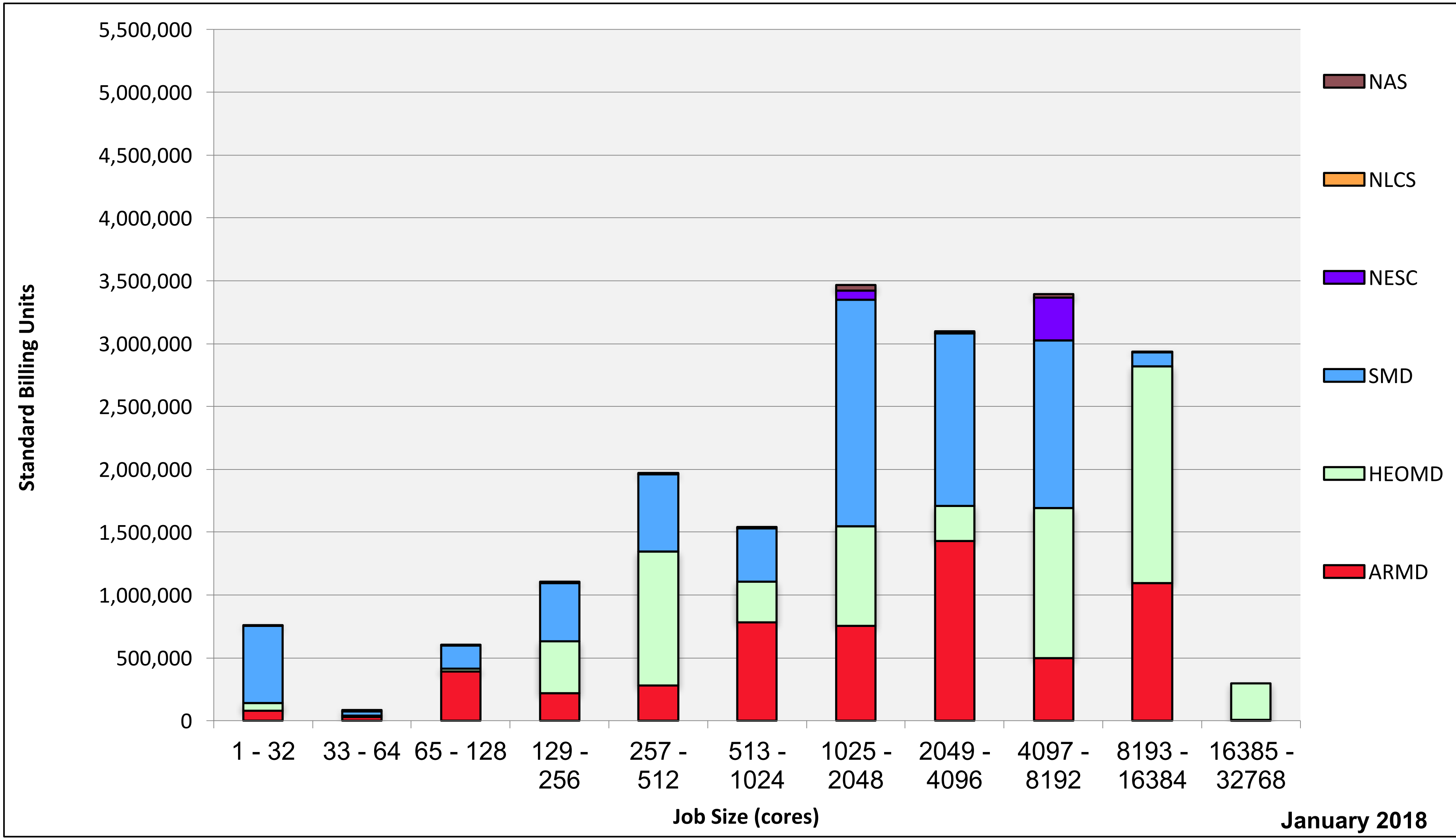
Pleiades: Devel Queue Utilization



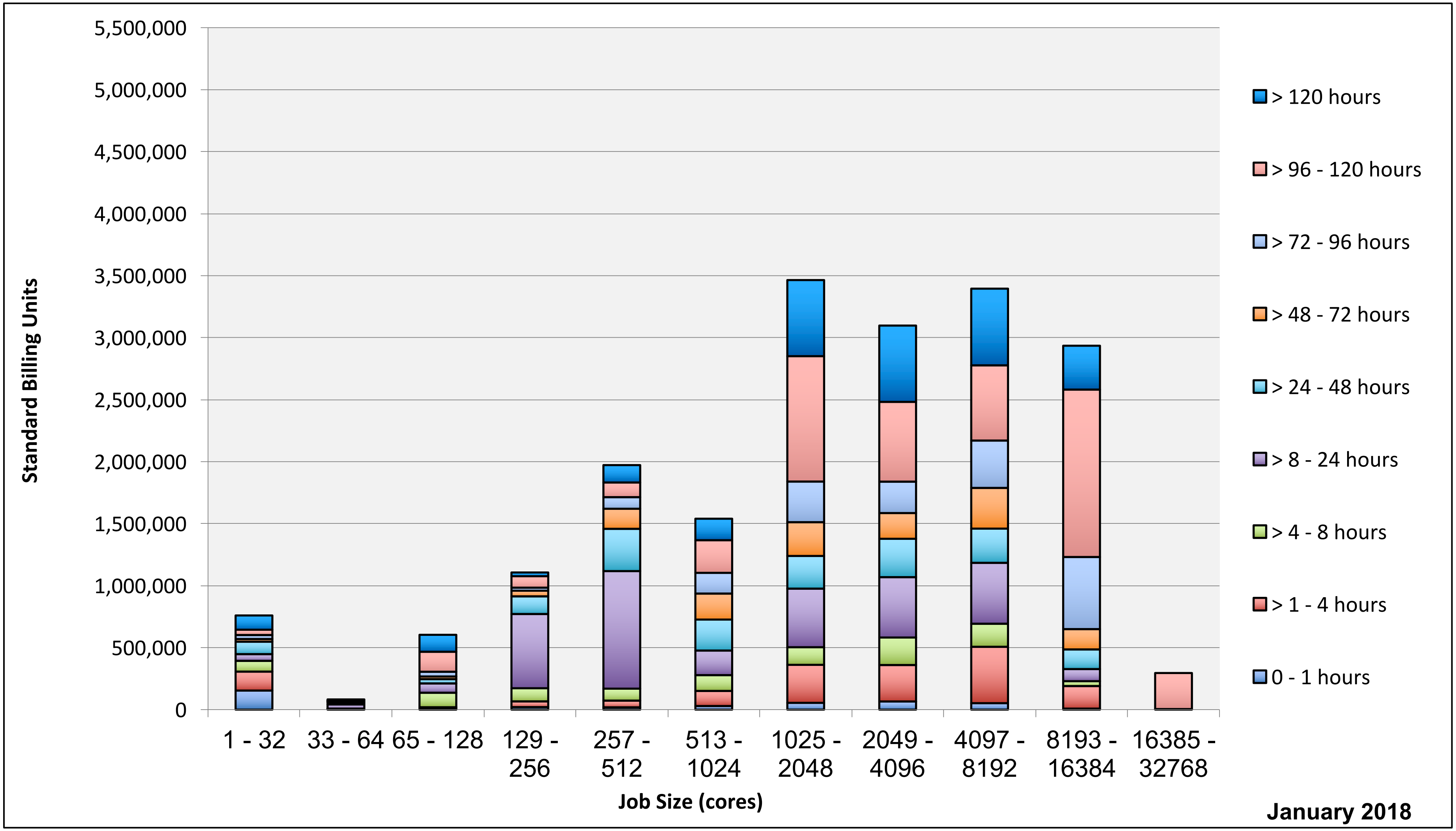
Pleiades:
Monthly Utilization by Job Length



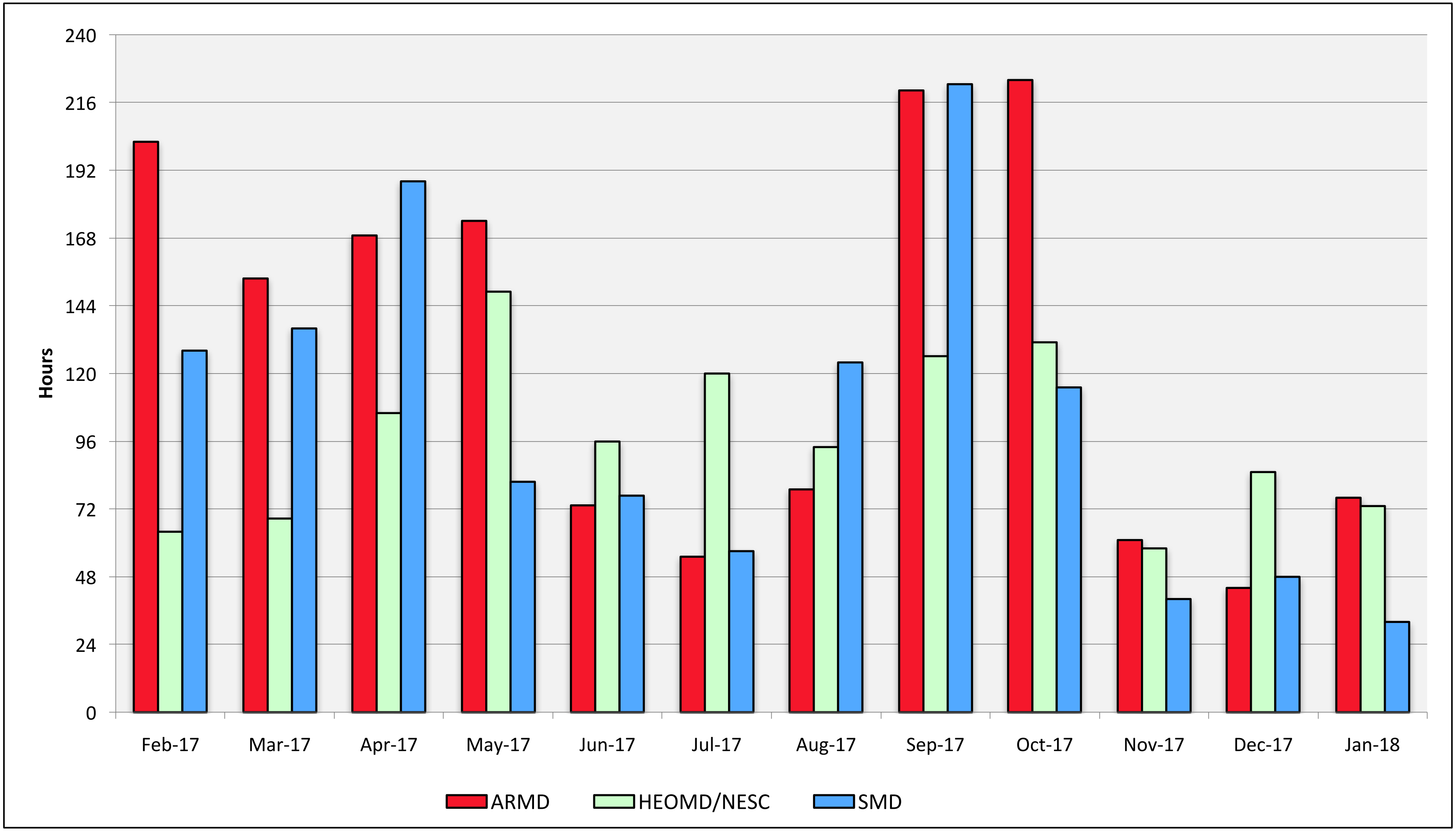
Pleiades: Monthly Utilization by Size and Mission



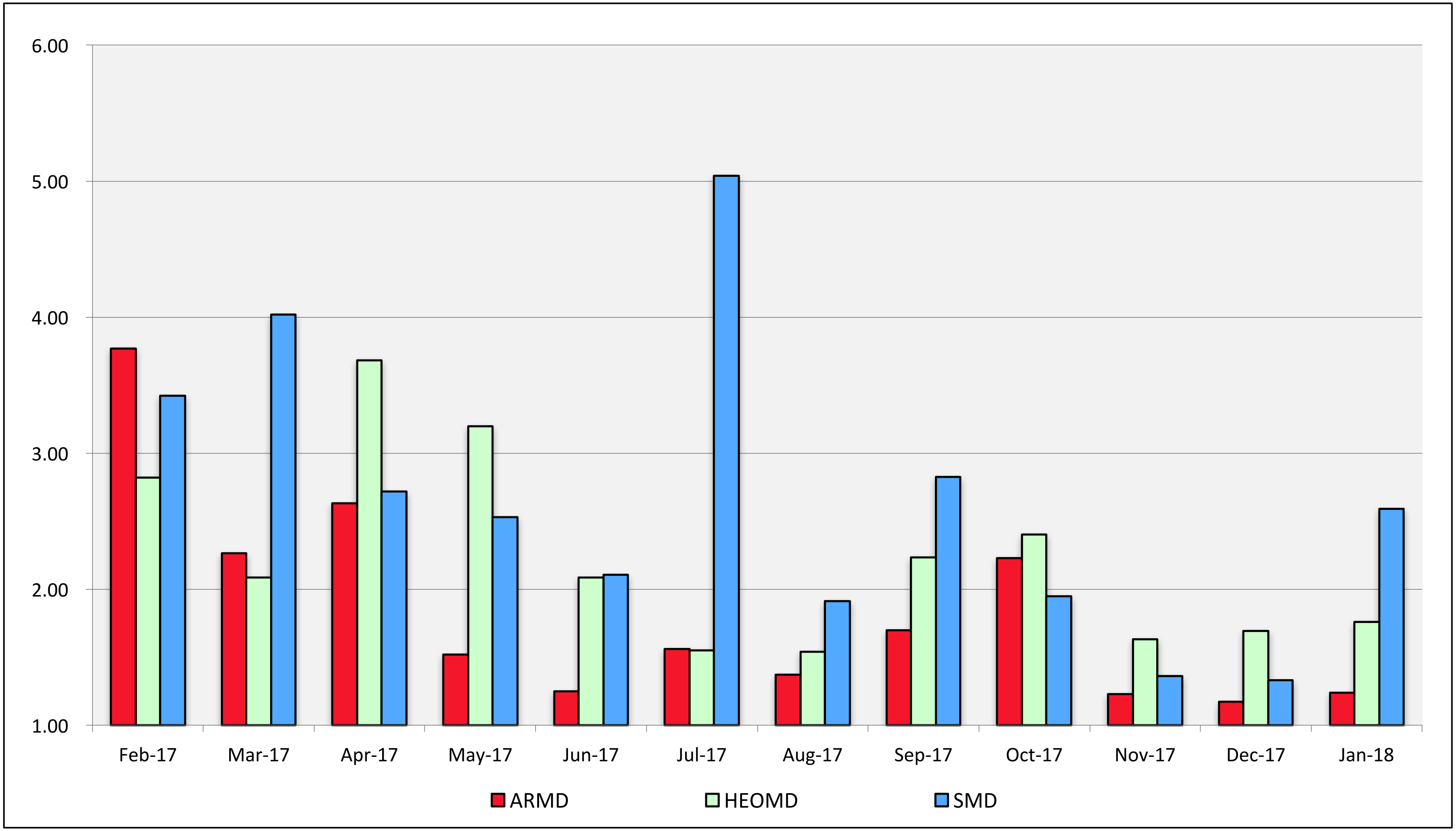
Pleiades:
Monthly Utilization by Size and Length



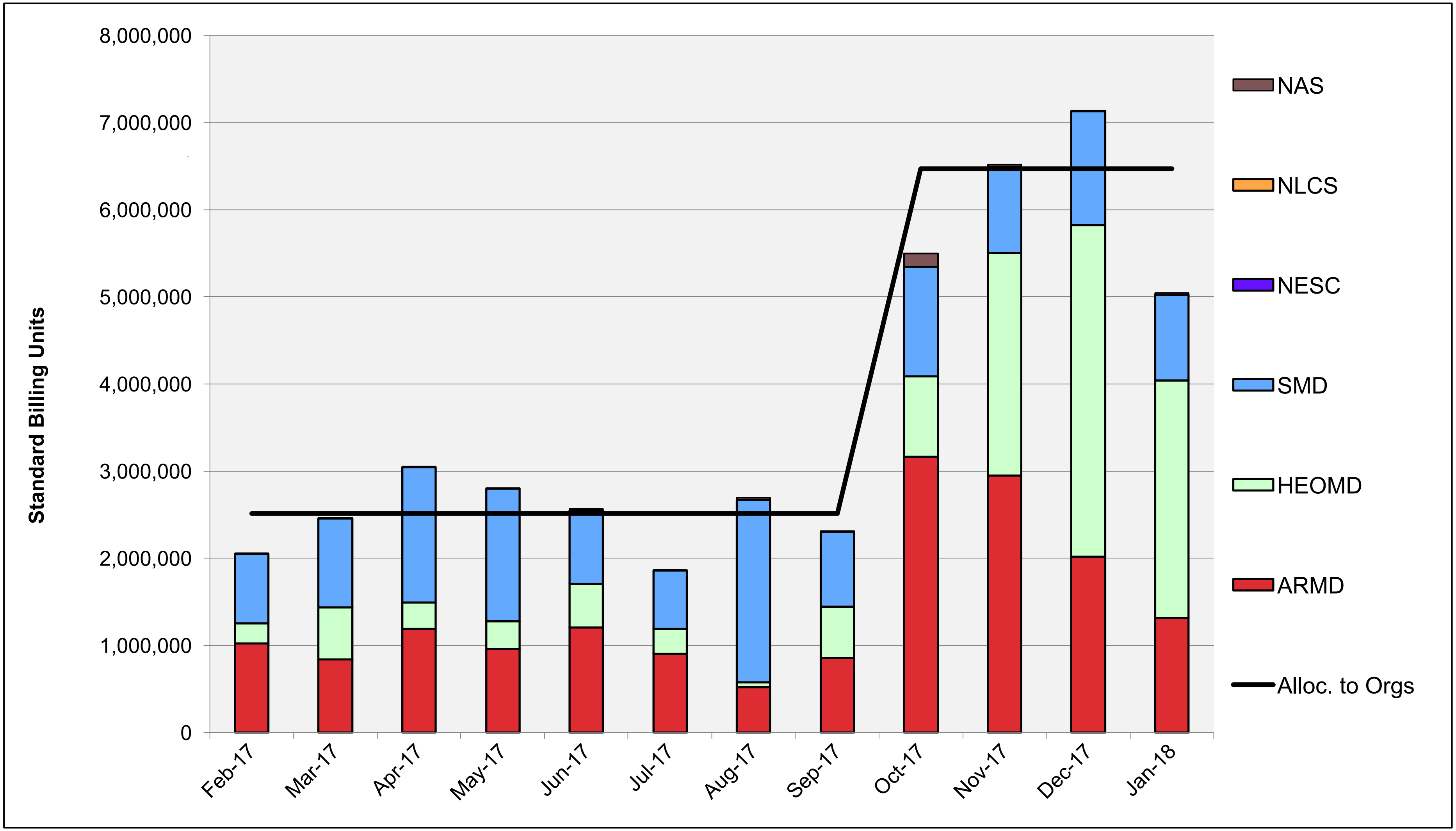
Pleiades:
Average Time to Clear All Jobs



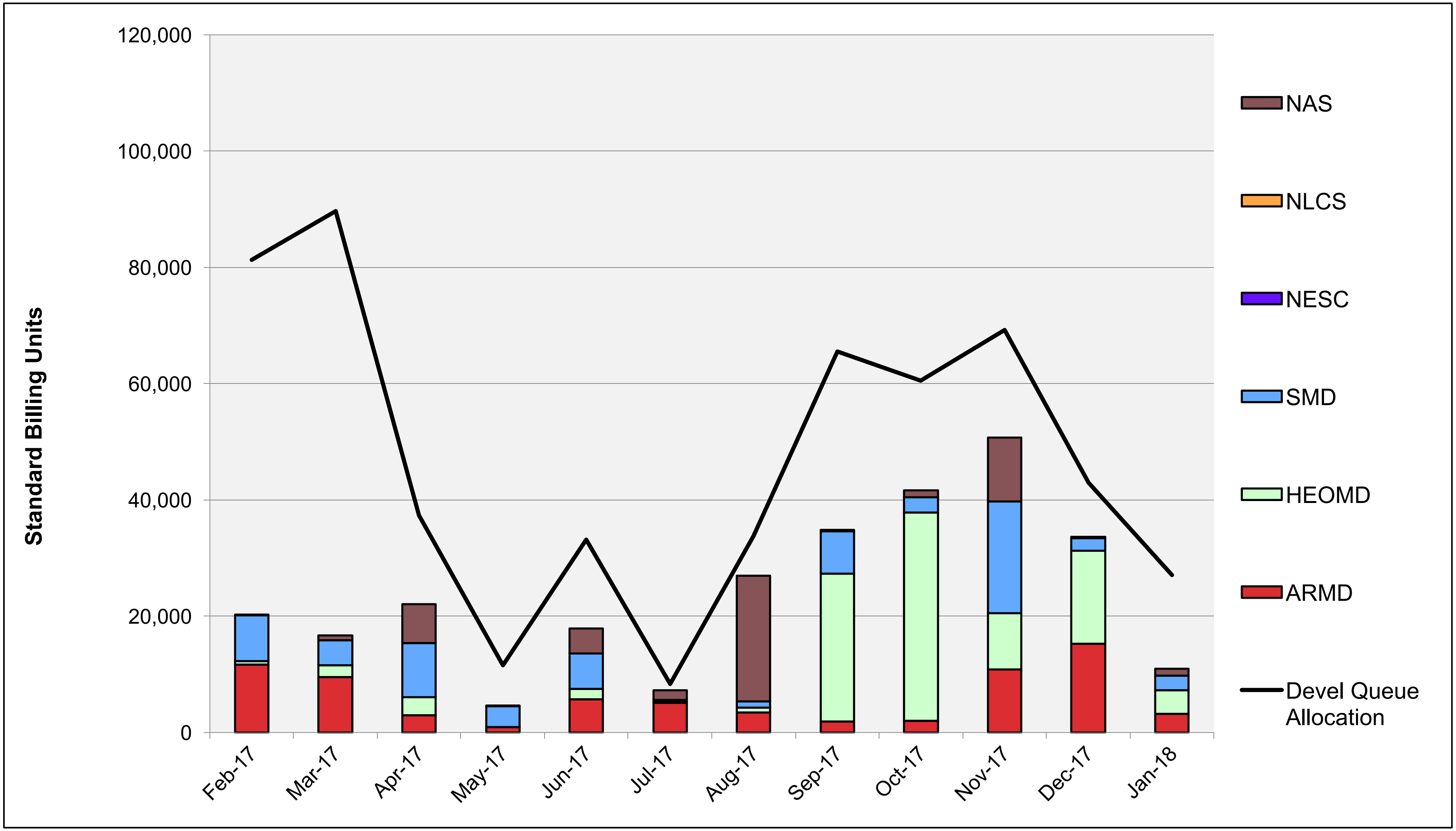
Pleiades: Average Expansion Factor



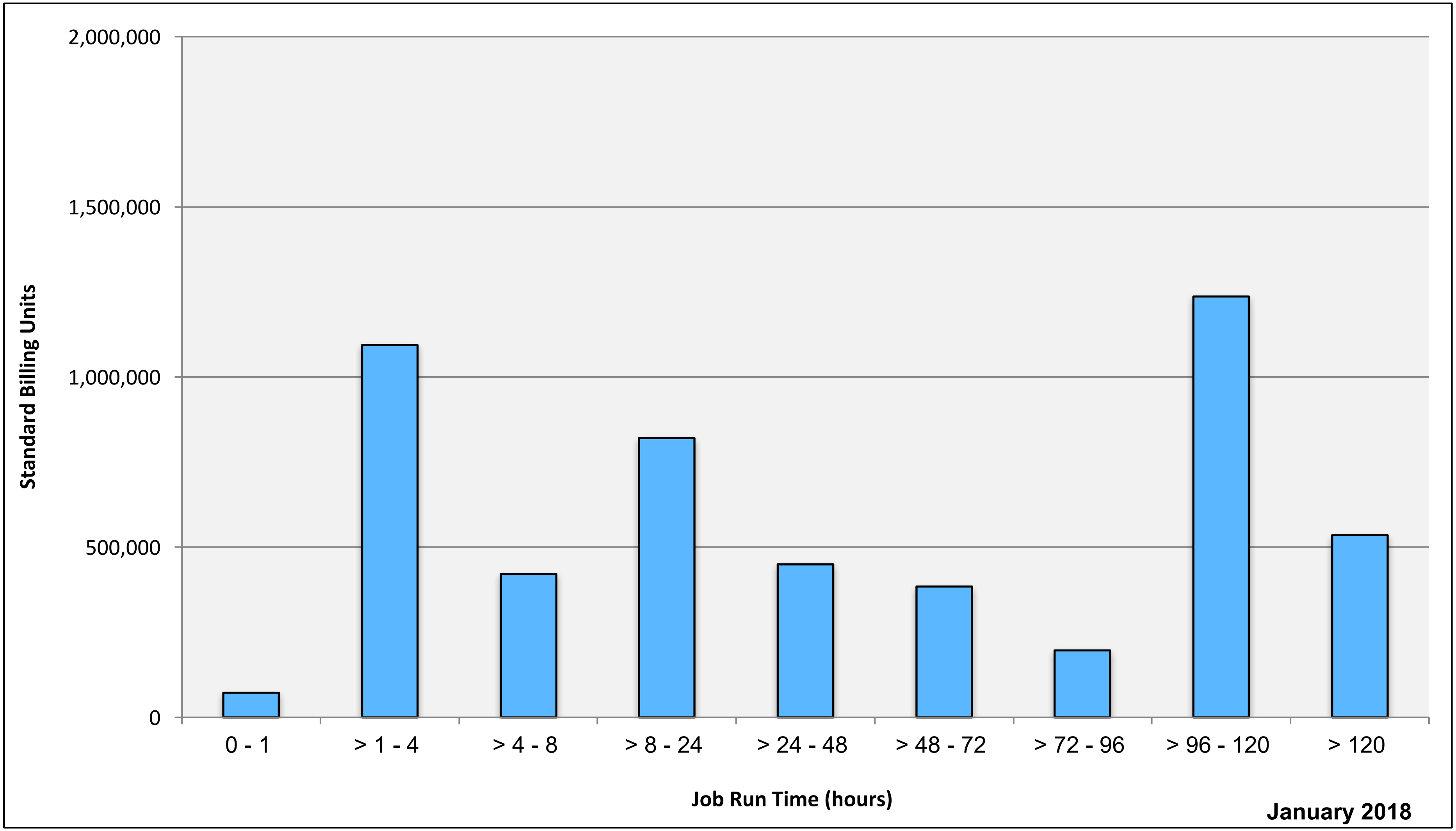
Electra:
SBUs Reported, Normalized to 30-Day Month



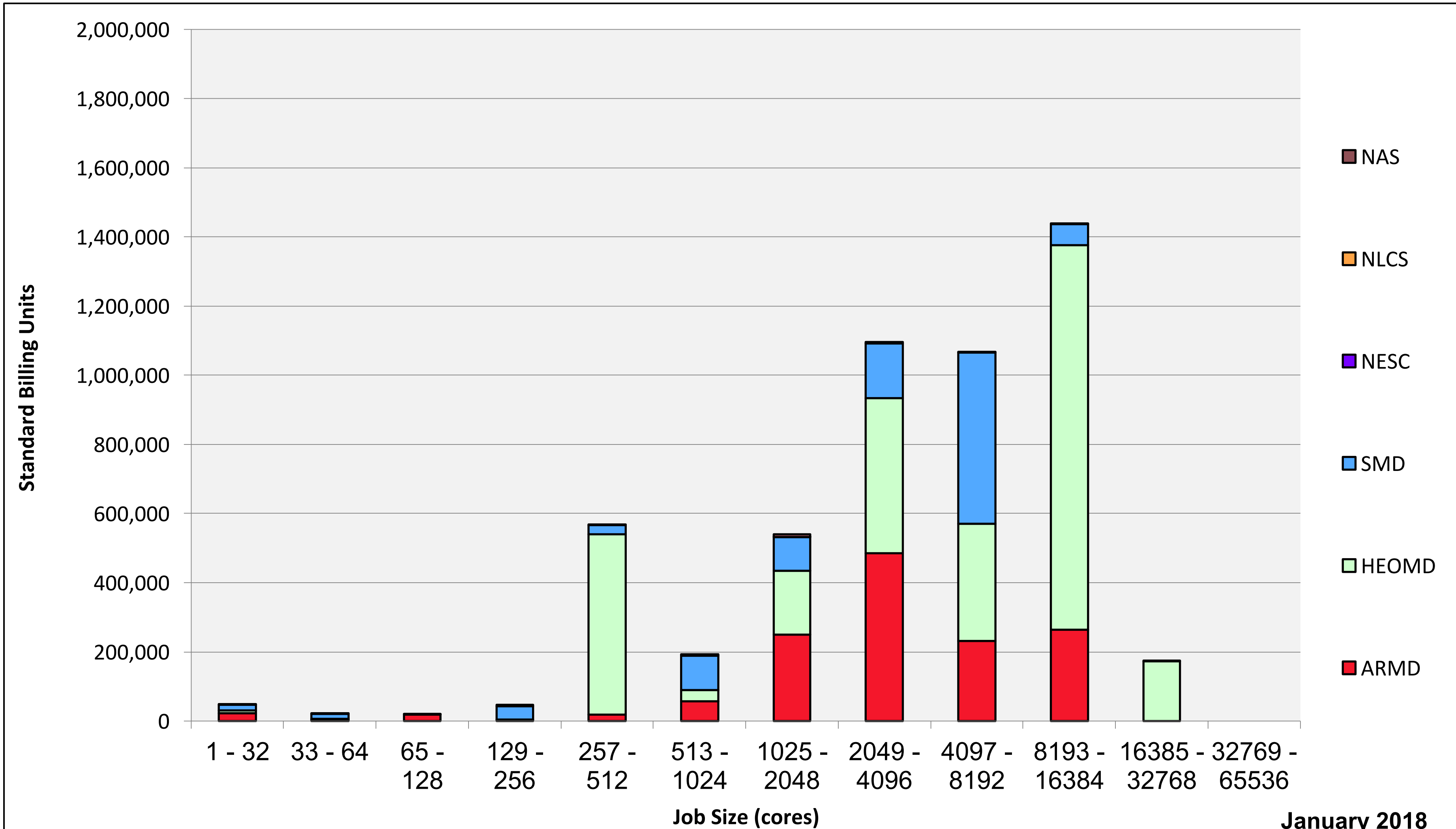
Electra: Devel Queue Utilization



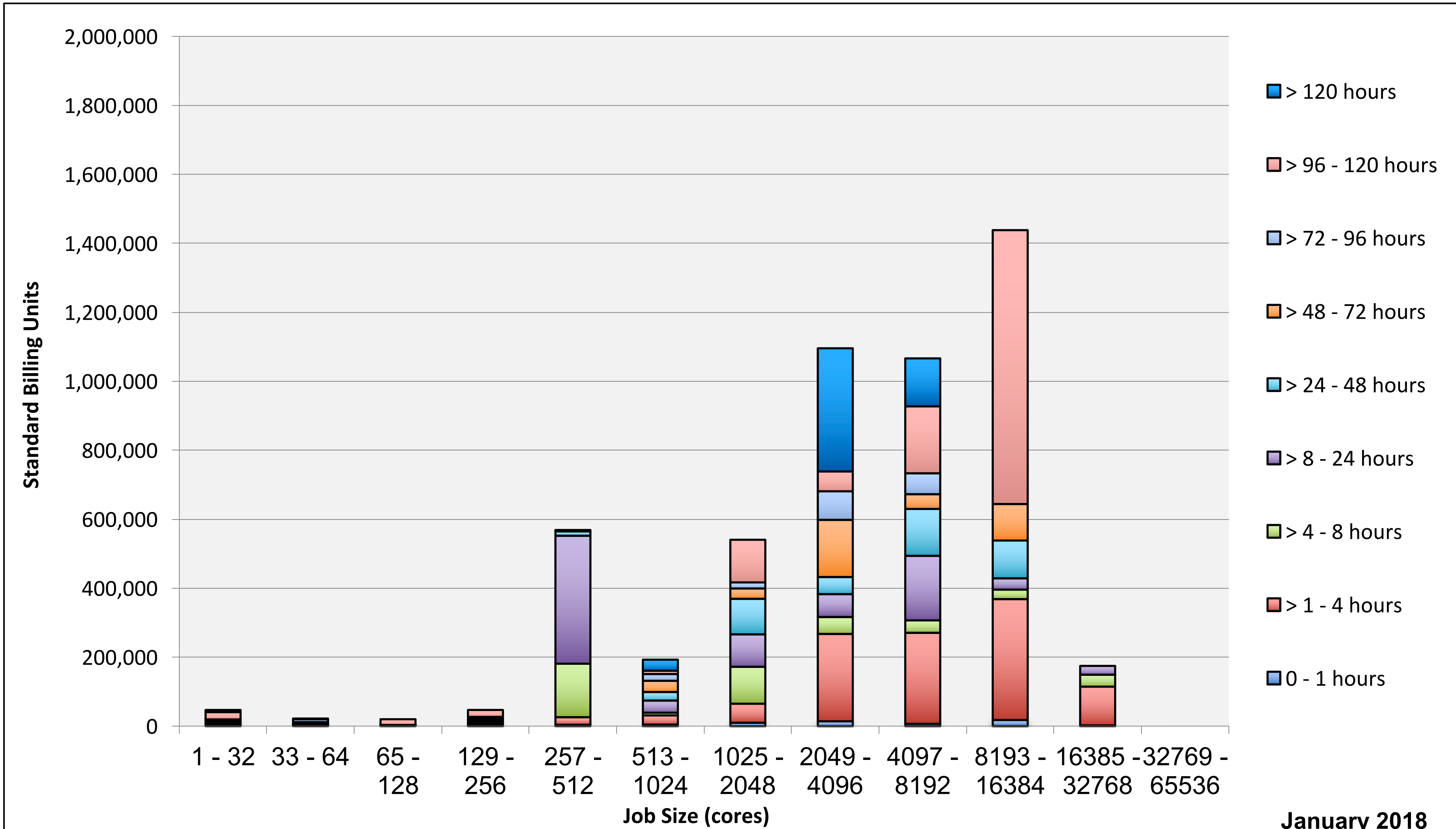
Electra: Monthly Utilization by Job Length



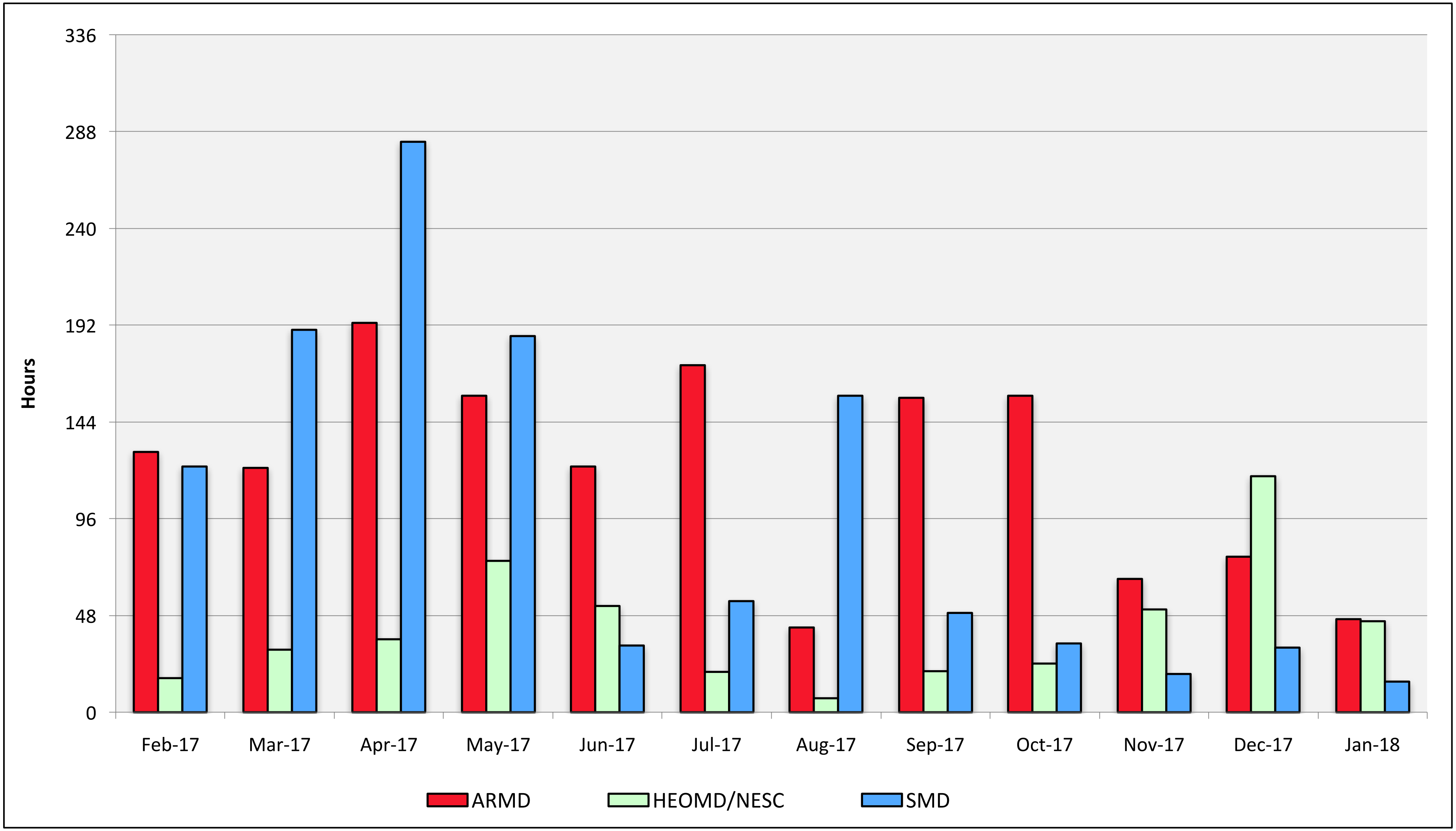
Electra:
Monthly Utilization by Size and Mission



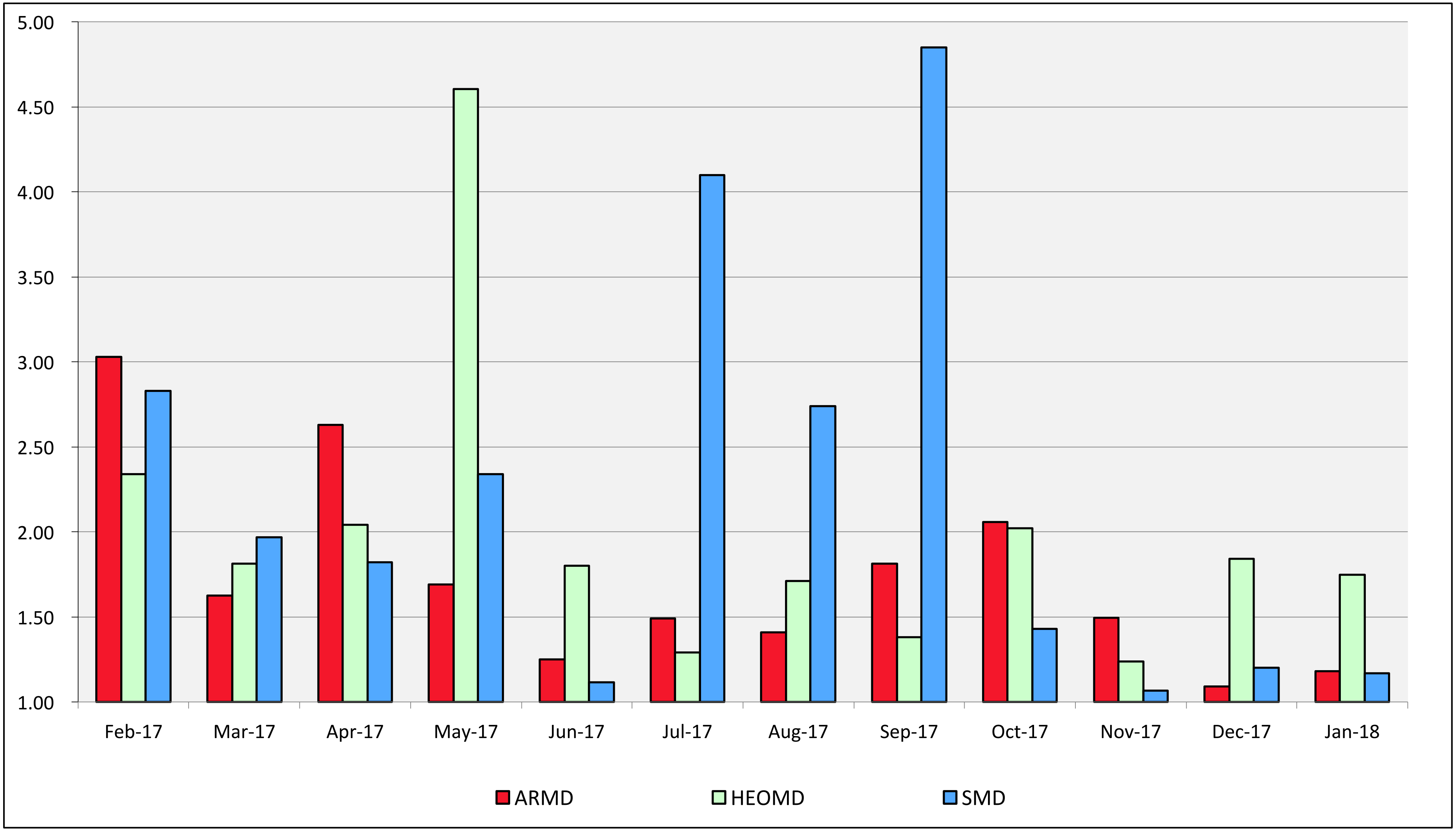
Electra: Monthly Utilization by Size and Length



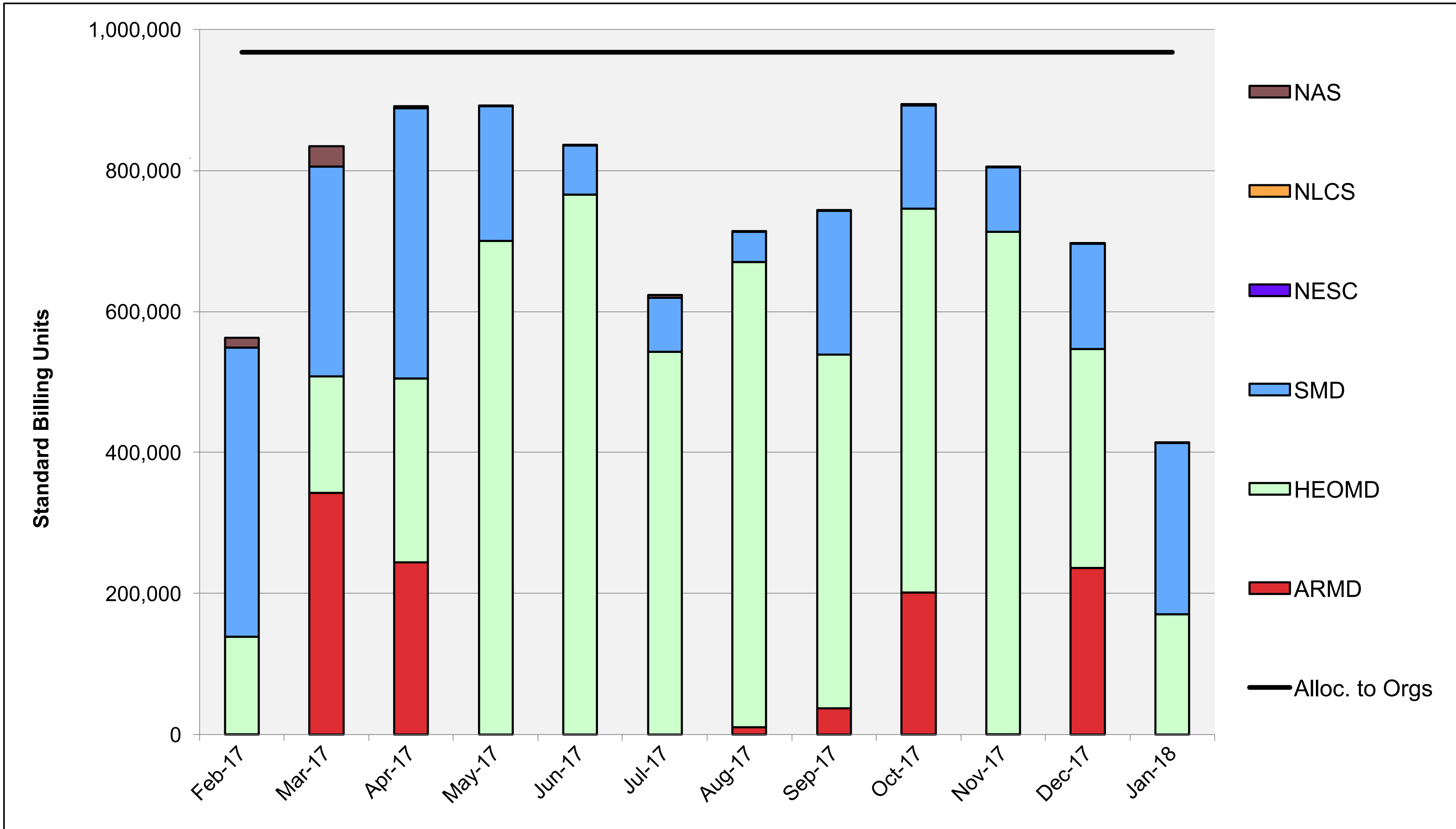
Electra: Average Time to Clear All Jobs



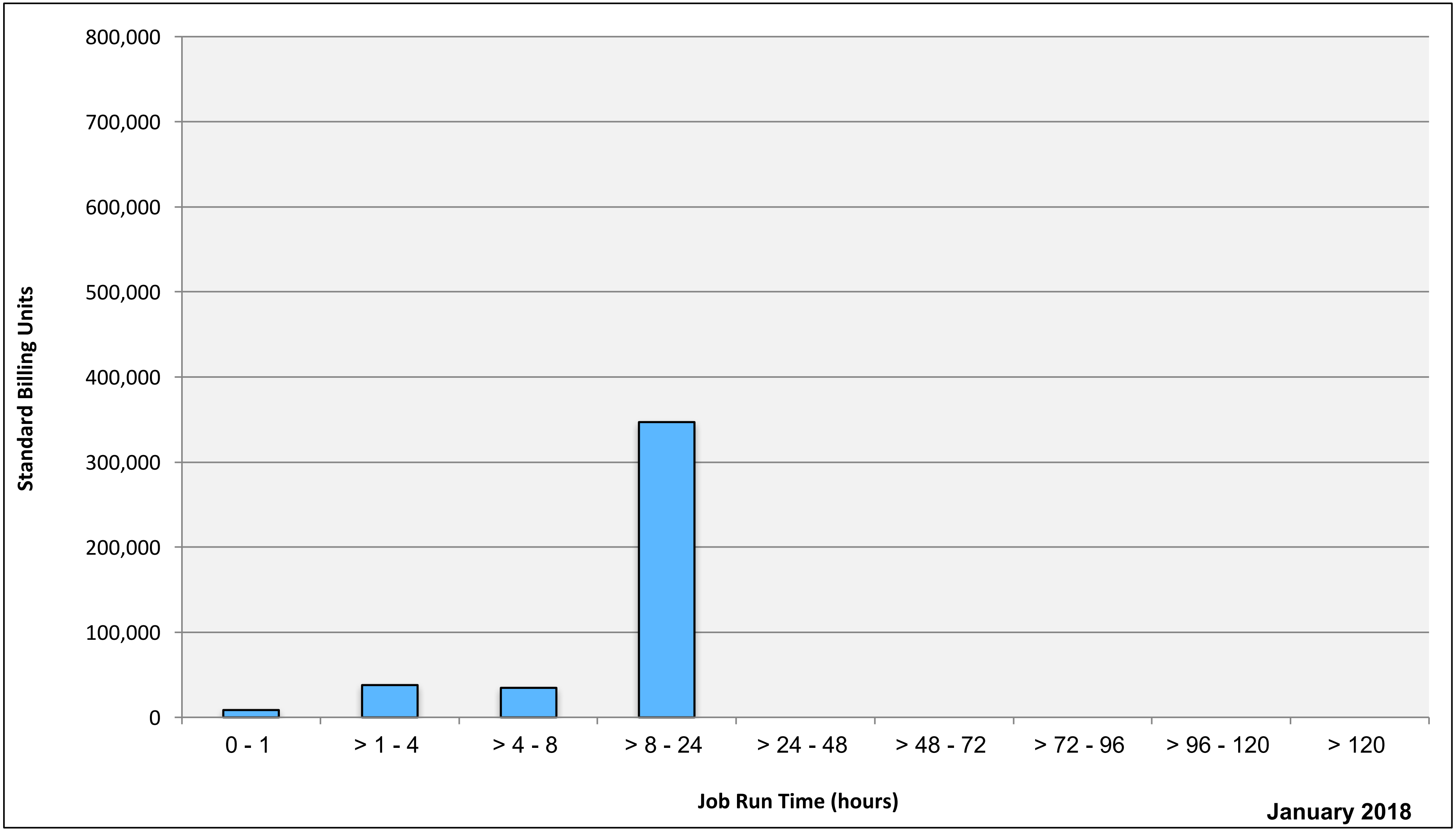
Electra: Average Expansion Factor



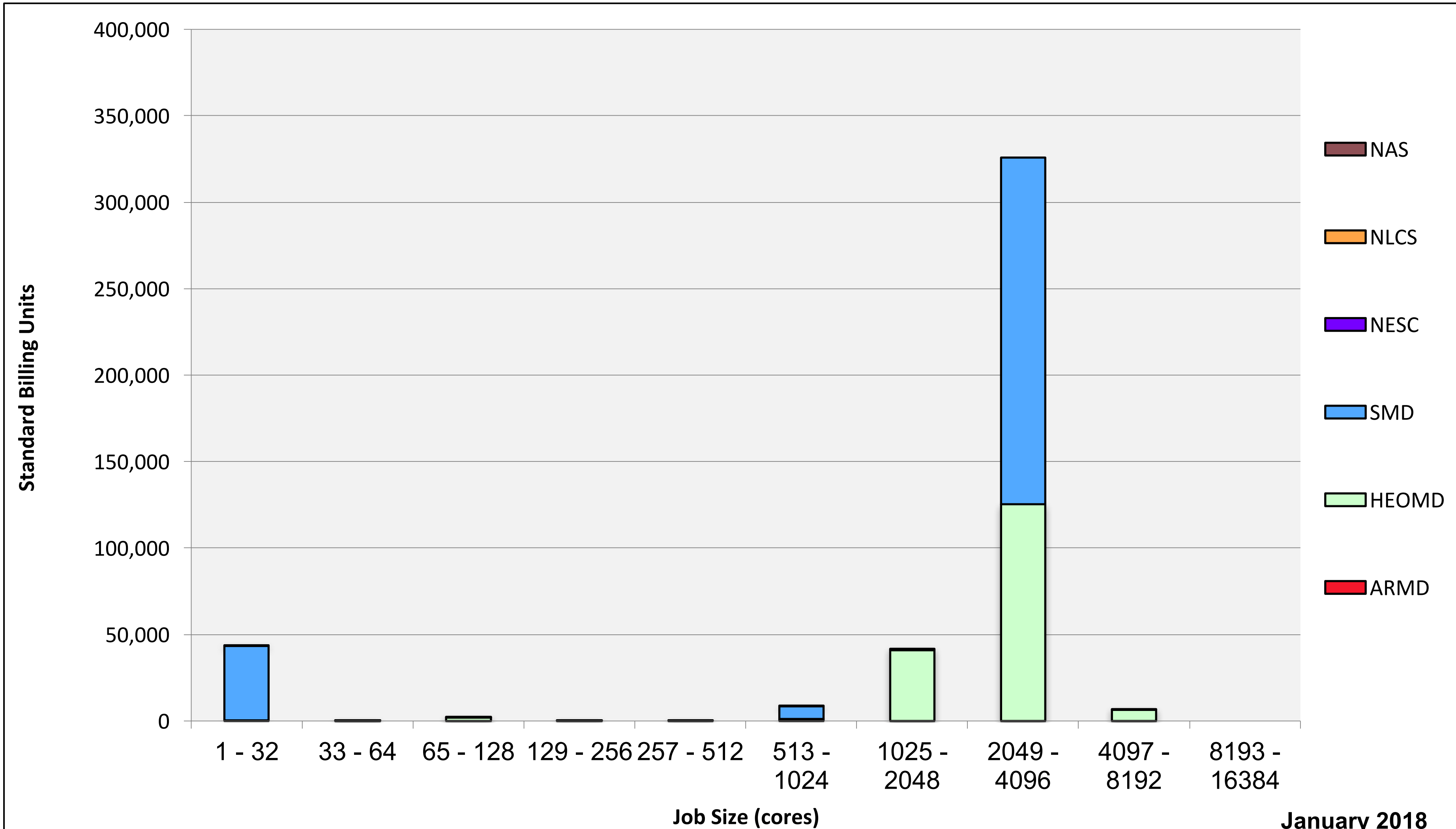
Merope:
SBUs Reported, Normalized to 30-Day Month



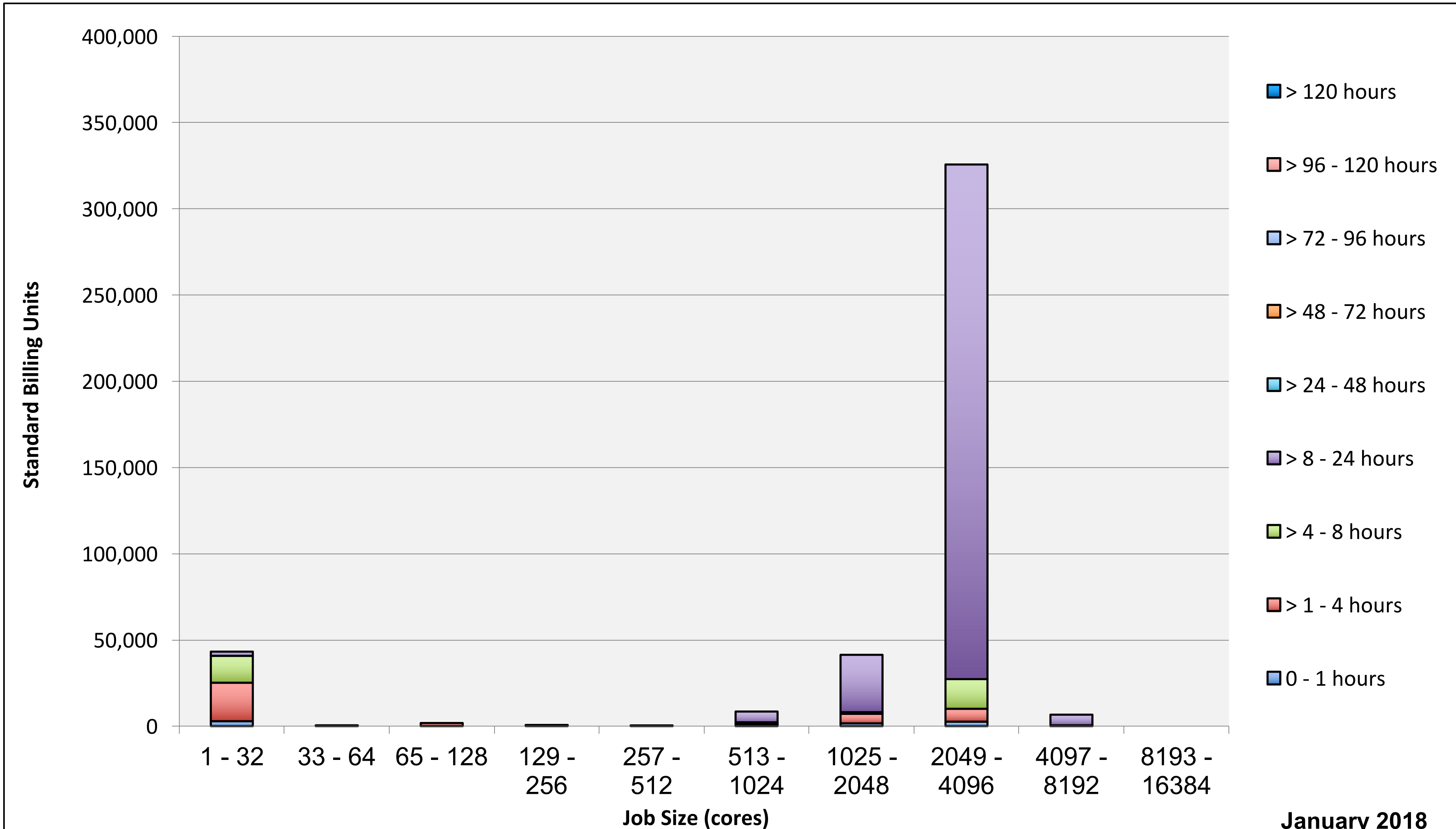
Merope:
Monthly Utilization by Job Length



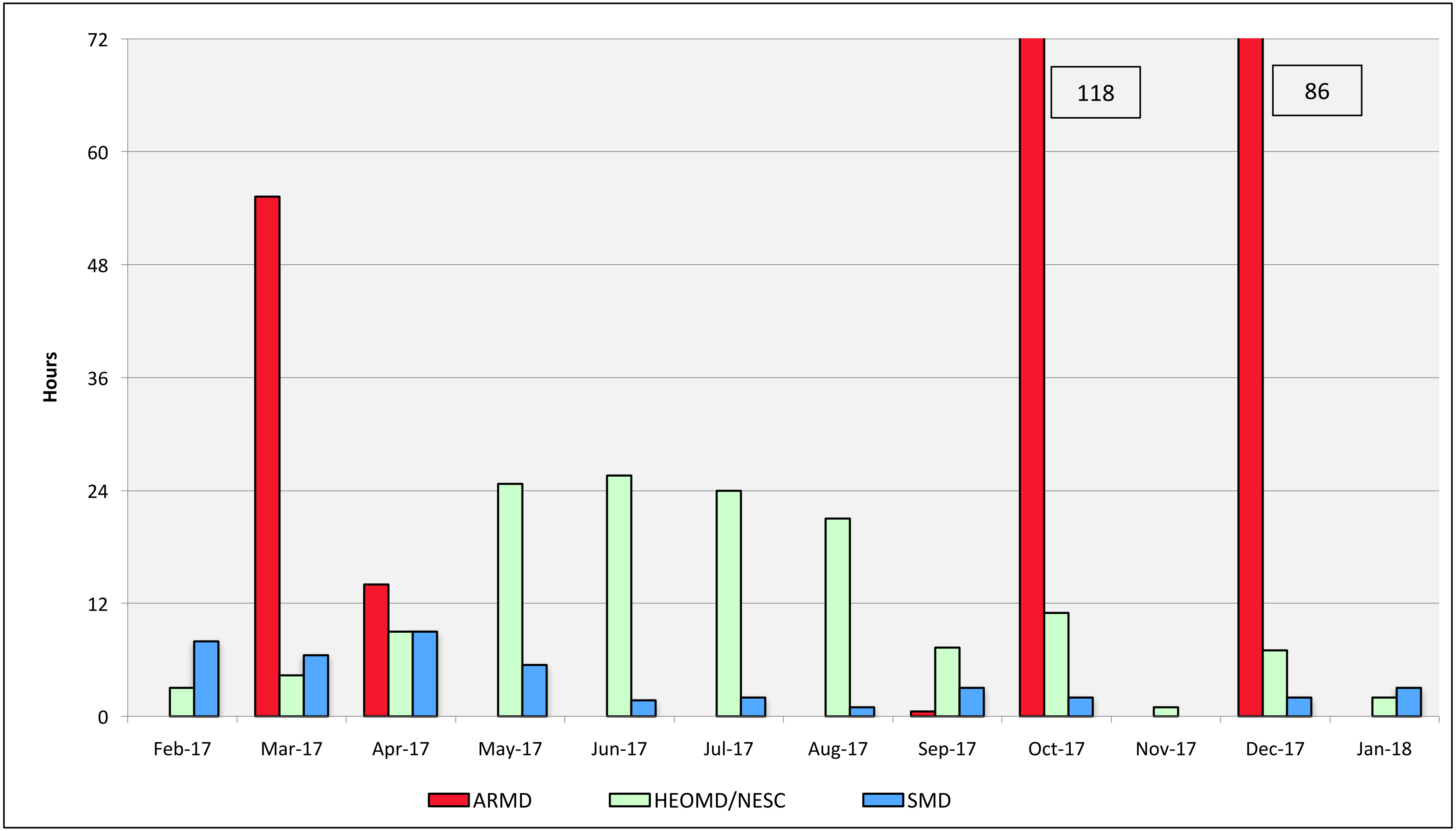
Merope: Monthly Utilization by Size and Mission



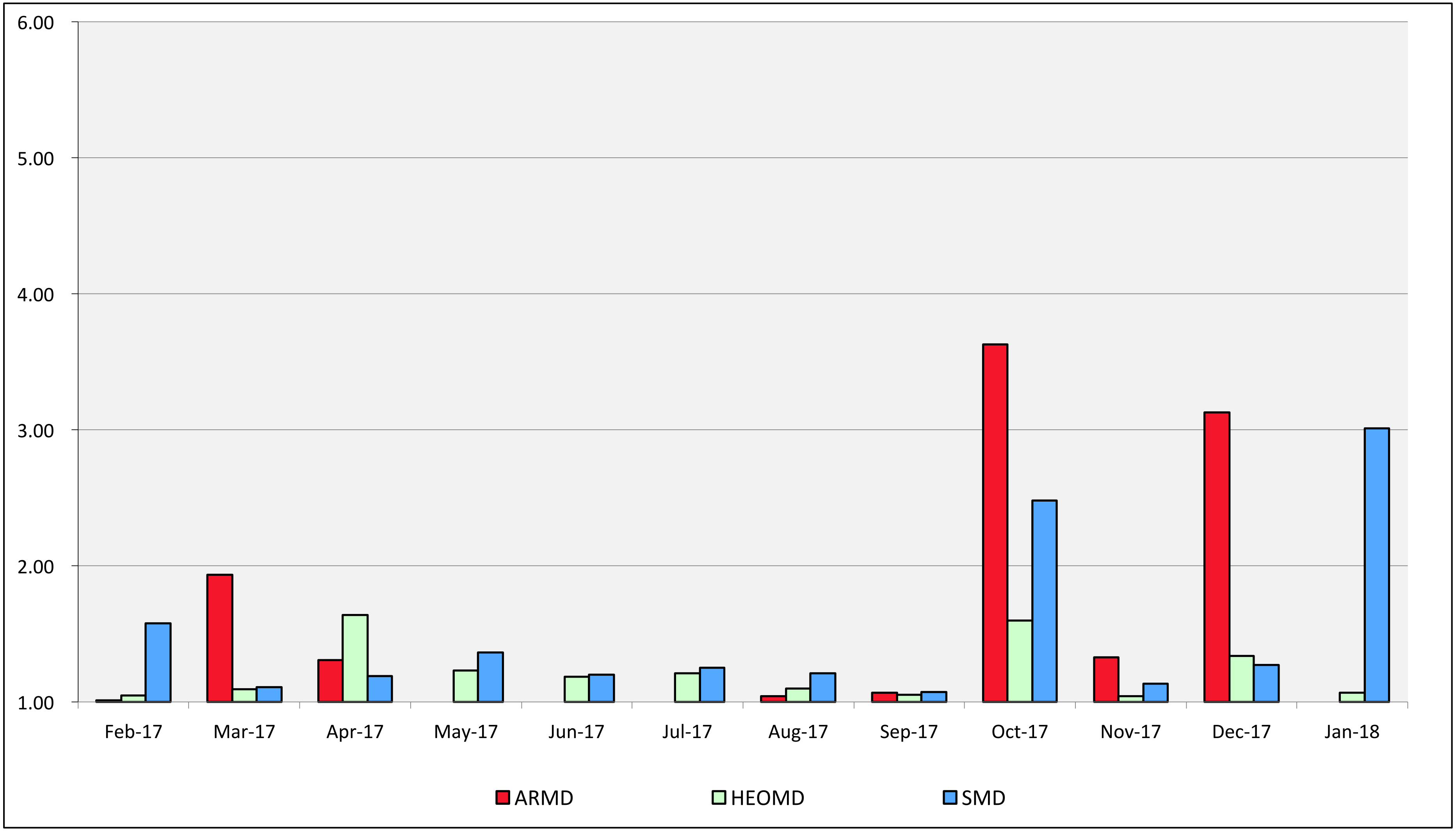
Merope: Monthly Utilization by Size and Length



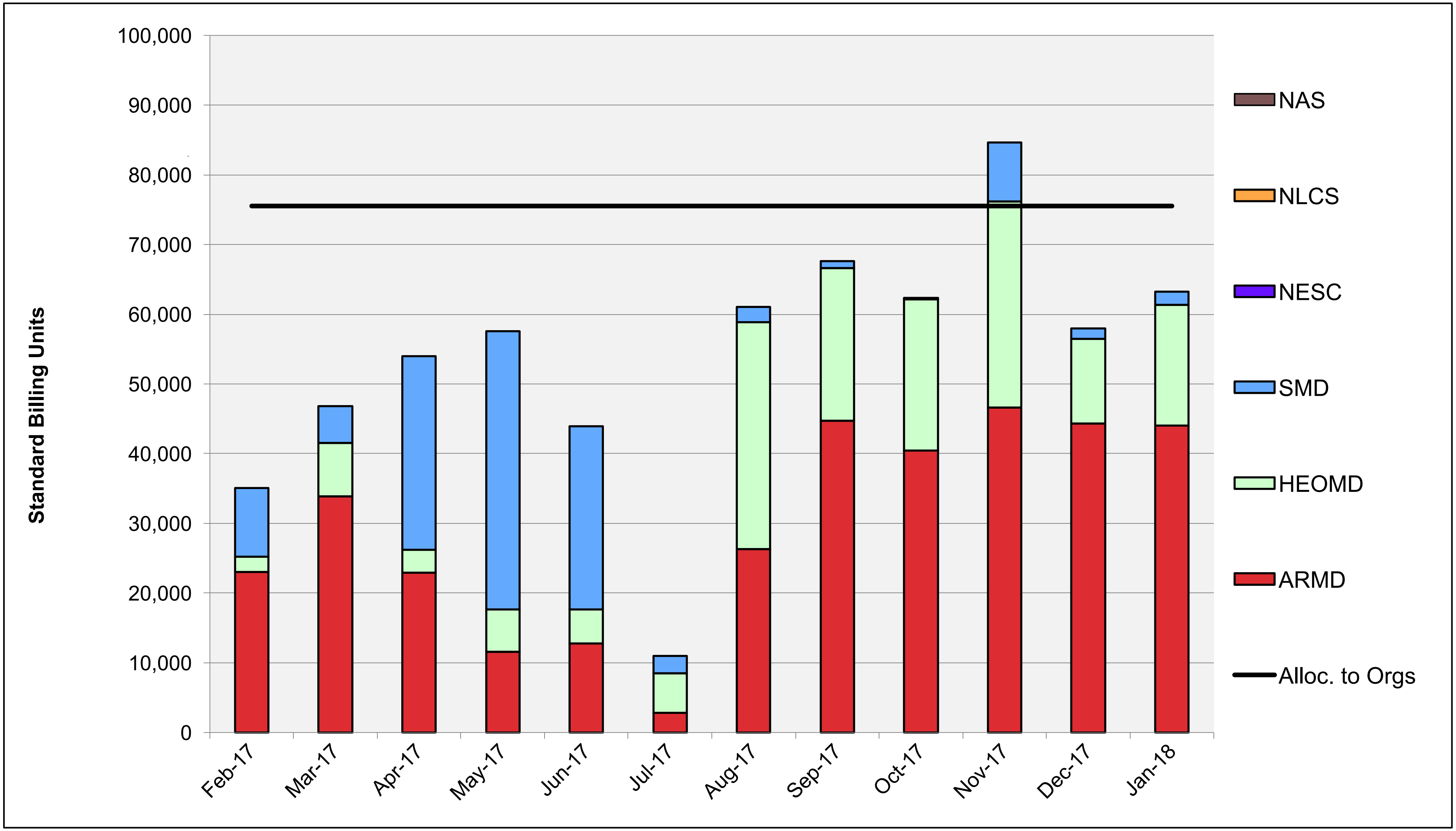
Merope:
Average Time to Clear All Jobs



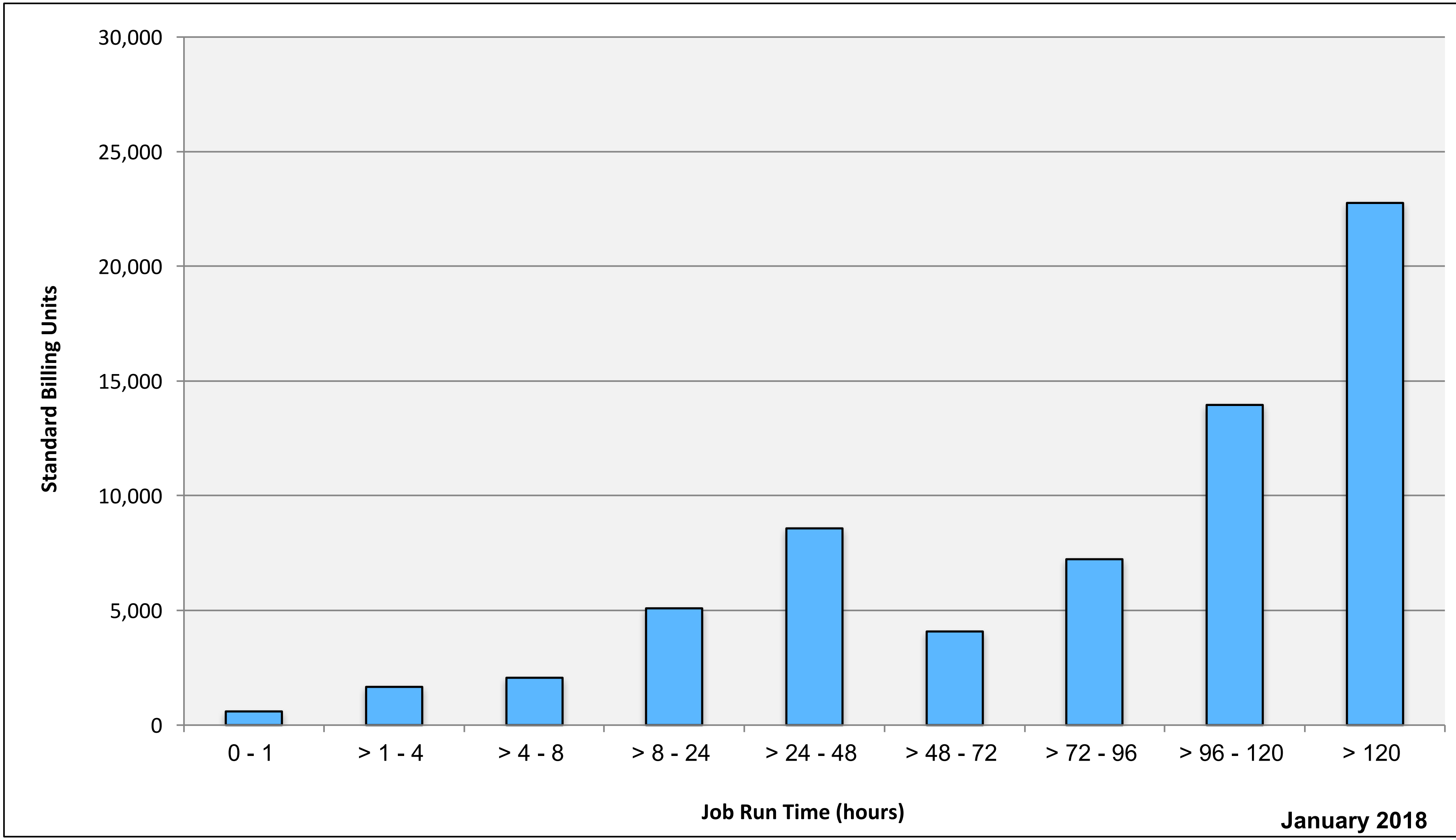
Merope:
Average Expansion Factor



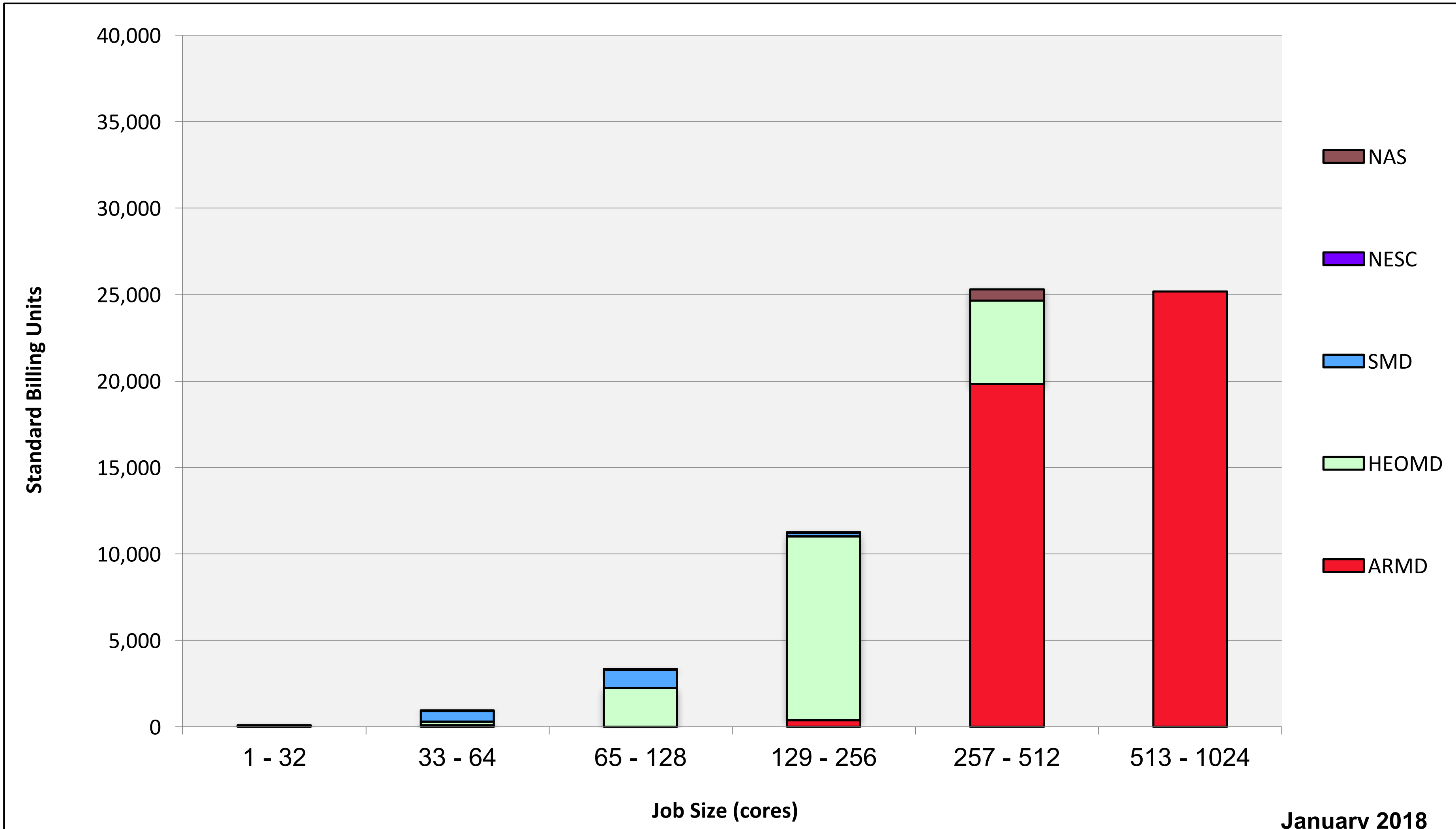
Endeavour:
SBUs Reported, Normalized to 30-Day Month



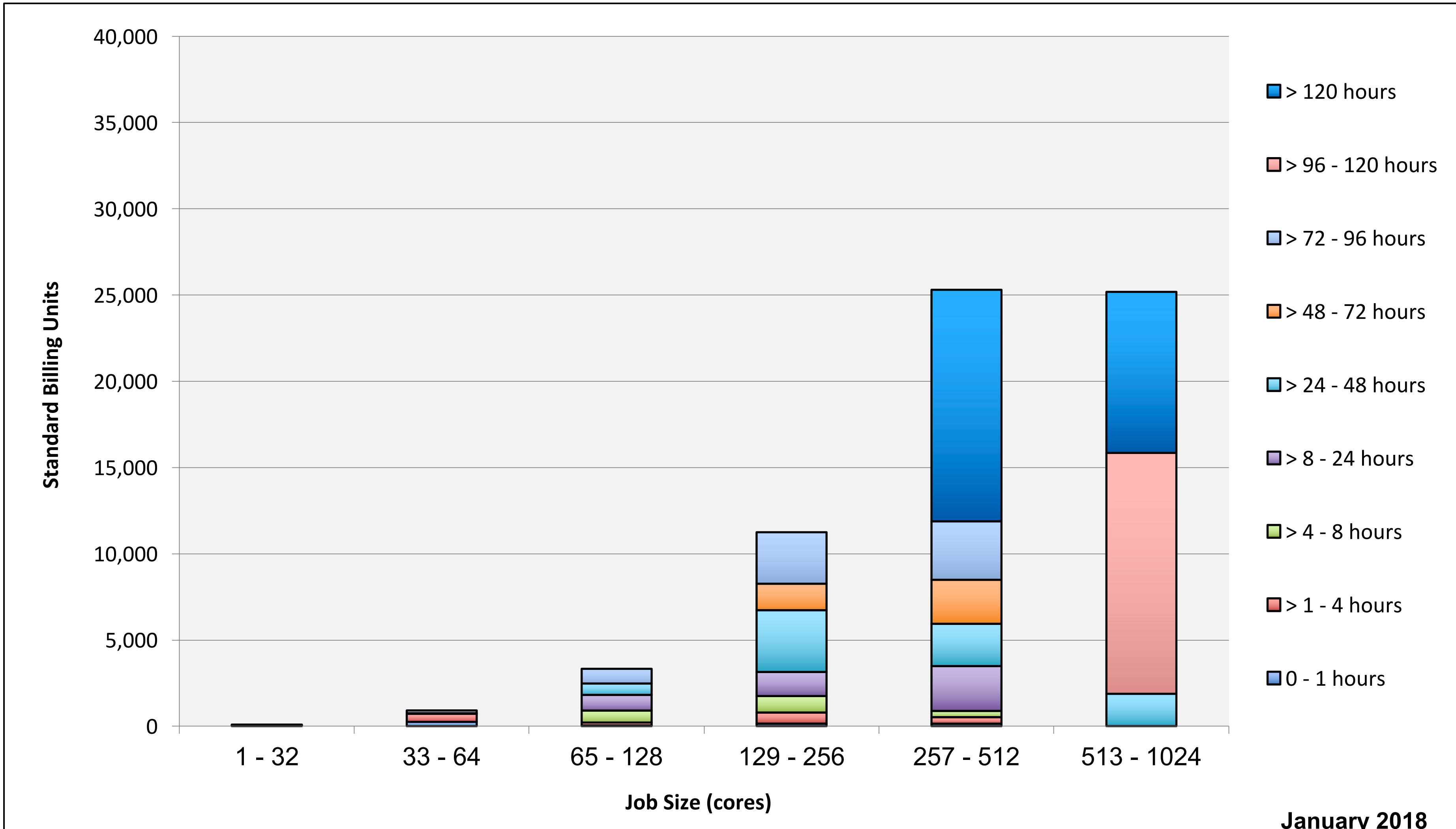
Endeavour: Monthly Utilization by Job Length



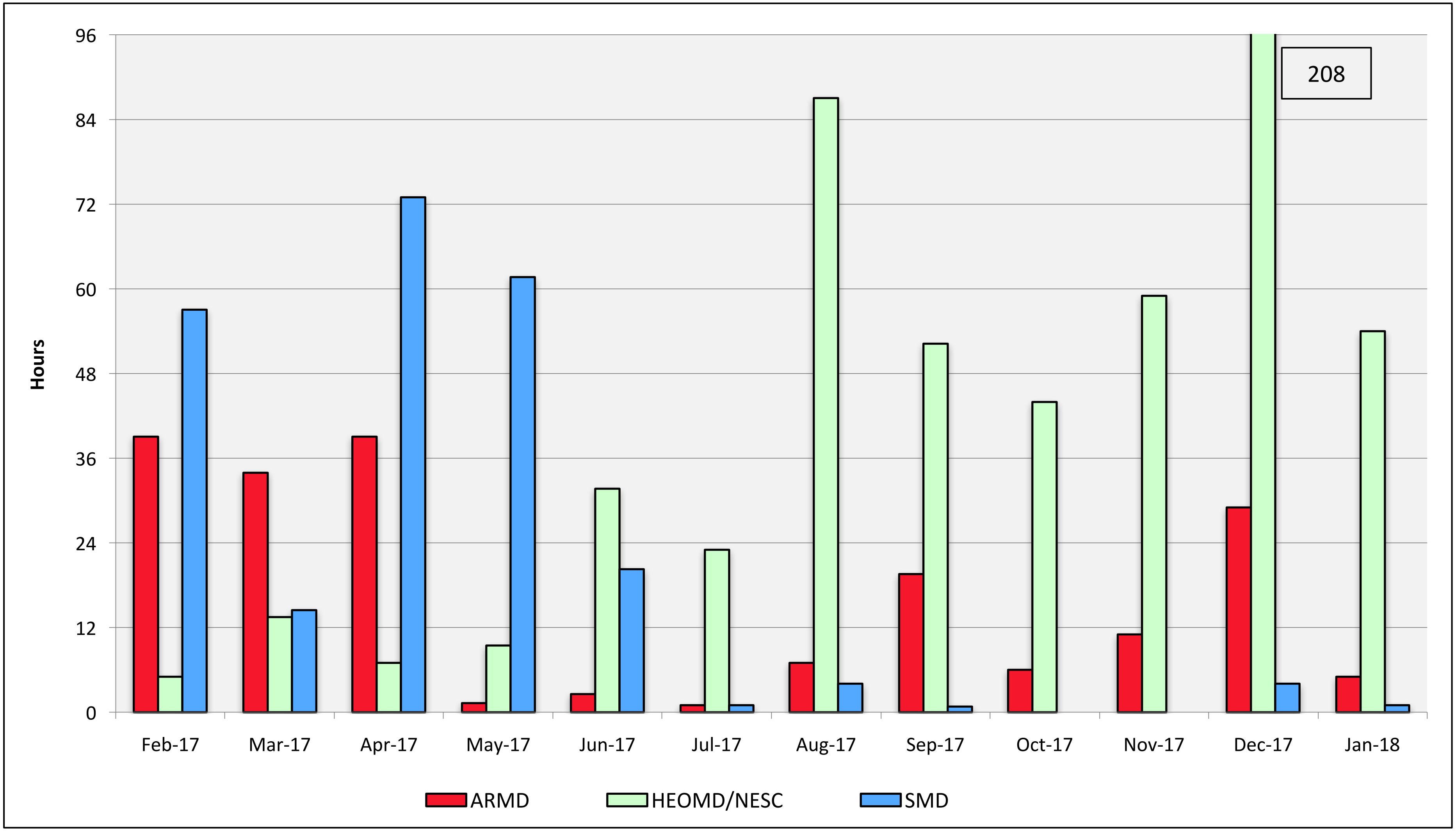
Endeavour:
Monthly Utilization by Size and Mission



Endeavour:
Monthly Utilization by Size and Length



Endeavour:
Average Time to Clear All Jobs



Endeavour: Average Expansion Factor